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Examining Environment – Economy Linkages

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The Canadian Environmental Advisory Council deserves both acknowledgement and applause for identifying this subject for study, and for its determined effort to promote thorough and continuing discussion. It is my hope that the efforts of the Council will stimulate thoughtful response, and will prompt further initiatives to expand our understanding of the interactions between the environment and the Canadian economy.

R.A. Knowles

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FOREWORD

The Canadian Environmental Advisory Council (CEAC) has been interested in the linkages between the environment and the economy for some time. Intuitively we have felt that environmental planning and management are cost-effective and fundamental to a sustainable economic future for Canada. This report reflects an effort by Council to be more specific, to begin to document the linkages, to take a preliminary look at current literature in the field, and to develop useful methods for understanding environment-economy relationships. Without this understanding, Canadians will continue to make both economic and environmental decisions without appreciating how important they are to each other. The natural environment is, after all, the support system for all forms of human activity.

This paper proposes a way to describe and measure the relationship between Canada's economy and the natural environment. Certainly, history has taught us that some forms of economic activity can harm the environment. Fortunately, there is now a growing understanding that many steps taken to protect the environment can generate economic benefits and, moreover, that sustainable economic performance depends on protecting the environment. In other words, rather than being diametrically opposed, economic performance and environmental quality are different sides of the same coin. In addition, Canadians value their environment for cultural, aesthetic and spiritual reasons. In many cases, these values in themselves provide all the justification that is needed for intensive protection of the environment.

Although Council has focused on economic factors in this study, it does not signify that less importance should be attached to other environmental values. Nevertheless, from an economic standpoint, it is Canada's environment that provides the raw materials to drive the economic system. Ironically, it is also the environment that serves as the recipient of unwanted by-products from the economic system it feeds.

Many of our natural resources are commonly described as "renewable". But they are renewable only if carefully managed to ensure sustainable use. For those that are non-renewable, we have a special obligation to ensure their use is environmentally sound. In short, it is becoming clear that the durability of our society may well depend on the degree to which we apply a conservation or environmental ethic to the economic system.

This study of linkages between the environment and the economy involved carrying out a preliminary review of current relevant literature, identifying different theoretical perspectives, reviewing methodologies and analytical approaches, and searching selected databases to determine the availability and quality of data pertinent to a few sample linkages.

The research revealed that environment-economy relationships are extremely complex and, at present, imperfectly understood and described. It also revealed that sharp differences of opinion exist among theoretical economists concerning the interactions and dependencies between economic activity, human welfare and the natural environment. However, the diversity of views on the subject should not, in our opinion, deter further examination of the relationships. Nor should it distract us from encouraging greater understanding and awareness of the intimate relationship among economic performance, environmental quality, and the quality of human society. Finally, we should not await some far-off day when all differences of opinion have been resolved and mountains of specific data generated before we incorporate into policy-making some understanding of environment-economy relationships.

Council views this study not as an end in itself, but rather as a starting point: a starting point for Council in its examination of specific linkages and the related cost or value. However, most importantly, the study is a possible starting point for other institutions, groups, and organizations undertaking the in-depth examination of environment-economy linkages.

In the final chapter of this report a number of recommendations for future action are presented, along with a summary list of research that should be carried out. Council does not suggest that all studies in the field must follow the broad, holistic approach recommended in Chapter 3. For example, in some instances, narrowly-focused studies may be more cost-effective. However, such studies must implicitly or explicitly recognize the limitations imposed by a less holistic framework.

Council is convinced that further research on environment-economy linkages is needed to ensure that Canadian policy makers and others making decisions and formulating action plans, have a better understanding of the interactions that occur between the economy and the natural environment. The need for further research is urgent. Over the long-term, our socio-economic system reacts totally with, and is totally dependent on the natural environment.

Canadian Environmental Advisory Council

INTRODUCTION

Understanding increases daily about how inextricably our well-being is bound to the state of the environment in which we live. It is increasingly apparent that the decision-making processes of government and the private sector must be broadened to ensure that short term economic goals do not irreparably damage environmental resources and the future economic benefits that can flow from them. With this in mind, the Canadian Environmental Advisory Council sought to expand understanding of the interrelationships between environmental quality and economic performance and to improve its ability to analyse related issues and questions.

The logical commencement point for this research, it seemed, was to start from known information and use it to investigate unknown areas. It was proposed that identification of specific "known" linkages between environmental quality and economic performance could provide a basis upon which future research might expand. The research strategy also called for examining two sample databases in order to test the effectiveness of any proposed analytical framework for identifying relevant data and information.

While the logic appeared sound, a preliminary review of major theoretical literature (primarily environmental-economics) published in the last fifteen years revealed that the approach might be too simplistic. Environment-economy relationships are not simple. Nor are they direct or constant. The linkages between the environment and economic activities are not of a predictable "cause and effect" type. These linkages involve interactions that take place as result of systems of factors working in combination. The resulting effects on the environment, on a particular ecosystem, on a specific economic system, or on a part of a system, are unique. There are no absolute, quantifiable, constant relational values or coefficients that can be used universally or in simple formula fashion to calculate environment-economy effects. The linkages and interactions that occur are not analogous to chemical reactions for which the results are predictable and quantifiable. Rather, the linkages and interrelationships between environmental and economic systems are subtle and variable in almost every imaginable way. Chapter 1 summarizes some of the reasons for this variability.

This realization led the study team to reconsider and redefine its original research strategy. The literature review revealed that, despite the complexities involved, considerable progress had been made in developing analytical models to estimate environmental-economic effects of different policies and actions. It was concluded that a review of the analytical techniques and associated theories might provide a basis for developing an approach that could be applied to future investigation of these issues.

The research strategy, therefore, was revised to include the following:

— reviewing environmental-economics theory and principles that bear on these questions — see Chapter 2;

— reviewing analytical approaches and methodologies which have been developed to analyze environment-economy linkages and effects — see Annex 1;

— specifying a conceptual approach to examining environment-economy questions — i.e. an approach that would be of assistance in identifying the components, data and information, and the sequence of steps involved in assessing individual issues and problems — see Chapter 3;

— utilizing the approach developed above to carry out a preliminary search of several databases to gauge the availability of required data and information (the search would involve specification of several examples of environmental-economic problems currently significant to Canada) — see Chapter 4 and Annex 2; and

— preparing a summary of recommended directions for future research required to advance this conceptual approach to operational problem-solving status — see Chapter 5.

Because of the short time available to complete this research (one month), it was necessary to rely on readily available published information, books and monographs, etc. During library and database searches, some very current (sometimes forthcoming) literature and research studies were identified. It is clear to the study team that a body of information remains to be reviewed in subsequent research efforts. A partial listing of these references accompanies the bibliography. In particular, economic-environmental modeling work completed by Canadian researchers was very difficult to obtain. There may be relevant research completed, unpublished, or currently underway that is not cited in this study. It was not possible to confirm this in the short time available. Future investigations should explore this area.

INTERDEPENDENCIES IN MODERN SOCIETY

Until modern times, the concerns of individuals and societies about environment-economy relationships focused primarily on the impact of environmental change on man, e.g., climate, flooding, food supply, etc., rather than on the impact of man on the environment. In the modern, technological, densely populated world, human activity has a major effect on environmental quality through air and water pollution, deforestation and desertification, etc. In turn, environmental change affects economic activity.

The rate at which raw materials and services are extracted from the environment, and the rate at which consumed products and waste residuals are returned to the environment, have important implications for sustained economic growth, social welfare, and the long-term viability of the environment upon which the economic process depends.

The flows of raw materials, services, and wastes (residuals) constitute linkages between economic and ecological processes. The rates of residual discharge and the reabsorption capability of the environment are matters that lie at the heart of many critical economy-environment concerns. Although not always properly accounted for in economic theory (see Chapter 2), the economic effects of changes in environmental quality can include reduced employment in particular industries (often "renewable resource" industries such as fisheries, forestry, and agriculture), increased human and animal health costs, changes in land values, reduced food production, reduced profitability and productivity of some industries, and widespread loss of recreational benefits.

Environmentalists' concerns have traditionally centred on both the short-term and long-term ecological effects of the trend towards continuously expanding and accelerating the rate of extraction and discharge of materials from and to the natural environment. The economists' concerns have tended to focus on how man can best transform both renewable and non-renewable resources into goods and services for increasingly affluent populations. The emphasis of modern western society has been to promote and satisfy material wants through continuous economic growth. In this respect there has been only limited interest, until recently, in the connections between economic activity and environmental quality.

In recent decades there have been worrisome indications that modern industrial societies, and perhaps the world as a whole, could experience irreversible changes in human welfare as a result of environmental degradation, before market-based economic indices or measures would indicate a state of crisis. Public awareness — both of severe short-term and long-term health effects stemming from various industrial activities and accidents, and of starvation due to the collapse of agricultural economies, e.g., in Africa — has heightened these fears.

Awareness of the potential consequences of crossing irreversible environmental thresholds is gradually increasing among Canadians, and the issue is now the subject of public debate. The general public is beginning to notice the degradation of the natural environment — in terms of the loss of animal and plant life, the economic effects such as reduced worker health and shortened life cycles of physical assets through corrosion, and the loss of agricultural and forestry potential — in a qualitative, if not yet in a quantitative sense.

The general public and policy makers are becoming aware of the potential implications of continuous environmental degradation. These implications have been widely publicized in several studies that suggest drastic global environmental-economic decline (Limits to Growth, Global 2000, etc.). While a great deal of discussion has been stimulated, there are only limited signs of serious attempts to initiate needed remedies for obvious problems, e.g., declining fisheries stocks, diminishing forest reserves, deteriorating soil quality, declining water quality, and acid rain.

Why is there such difficulty in obtaining a consensus of opinion and agreement on policy and action concerning these issues? The difficulty stems from a number of considerations, including the economic perspective one adopts, and the ethical-moral value system by which one abides (see Chapter 2). It also stems from the uneven rate of economic development and from the distribution of natural resource wealth within individual countries and throughout the world.

The disparities in ownership of the resources, in technical and educational skills, and in the social and political power associated with the existing distribution of wealth, combine to inhibit change (particularly fundamental change) in economic organization or orientation. Such changes usually create economic winners and losers. In a democratic society, redistribution of economic benefits and costs may therefore occur slowly because various interest groups resist change.

The issue is also complicated because environmental and economic effects vary in size and degree at both micro (local and ecozone) and at macro (regional, provincial and national) levels. In addition, at different levels of aggregation, many of the same individuals, firms, communities, and elements of the environment interact and generate different economic consequences. This is due to the synergistic effect of the interaction of many environmental factors and economic processes.

For example, certain forest harvesting practices may directly affect the surrounding environment by modifying the surface run-off and increasing the rate of soil erosion in clear-cut areas. Other effects of these practices may include:

— reduction of the soil's ability to regenerate stands of marketable timber; and

— indirect effects on other local commercial activities, such as fishing, through increased rates of siltation and deposition of logging debris in the spawning habitat of local rivers and creeks.

The economic effects of these forest harvesting practices, while perhaps optimal from the point of view of forest industry economics, may cause a dramatic decline in local fishing industry income, and reduce employment in fish processing and related service industries.

The interaction of economic activity and various ecosystems within the total environment, may have quite different consequences at a regional or national level. The relationship between economic players (i.e., the businesses, employees, residents, visitors, tourists, and governments) will differ at each level. At a local level, direct and personally-felt effects will be experienced by resident individuals and groups. These effects are often immediate and short-term. However, the economic impact of environmental change may be felt in quite different ways by these same individuals and groups as residents of a region or as citizens of a nation.

For example, a decline in forest industry activity due to the depletion of forest resources may result in lower provincial government royalty revenues. Indirect economic effects of this decline in revenue may include reduced expenditures on public transportation, health, education, or other governmental services. At the national level, there might be a reduction in exports (e.g., forest and fish products), which may affect the nation's balance of trade, the national deficit and currency exchange rates with other trading partners. Ultimately, these effects on the national economy have local impacts including changes in the purchasing (consuming) power of, in our example, logging and fishing firms and their employees.

Sometimes these environment-economy actions and interactions at local, national, and international levels involve perverse situations. For example, individuals (loggers or fishermen or others), businesses (forest companies or fishing companies), or governments (royalty collectors), find that there are rewards, in the short run at least, through overuse of a resource or by permitting adverse environmental change to occur.

Maximization of profits, royalties and employment are individual, business, and government goals. In certain circumstances, these goals can lead to increased forest cutting rates or fish production quotas, even in the face of declining sustainable yields. If economic conditions are poor, and if international market conditions give the Canadian forestry and fishing industries a comparative advantage over other producers, it may seem rational, in the decision-maker's mind, to place a higher priority on "economic goals" and to treat the "environmental trade-offs" either as if they were unrelated to future economic activity, or as if there will be no future consequences from the action.

If one traces the effects of examples such as the forestry situation described above, it is readily apparent that environmental and economic systems interact at international, national, regional and local levels through complex relationships within themselves, with each other, and with society's members. Research studies and actual experience in both industrialized and less developed nations have demonstrated that the environment of a particular locale, region, or nation should not be considered as either discrete from global ecosystems, or immune from the effects of actions taken elsewhere. The evidence is now overwhelming that all economies of the world are, to a degree, interdependent and interacting. This means that changes in environmental well-being inevitably affect both our own economic well-being and that of others.

Figure 1 depicts conceptually the interdependency that can exist between two environmental-economic systems. This possibility exists at local, regional, national and international levels. In realty, of course, some interrelations will involve not simply two systems, but many sets of systems and subsystems.

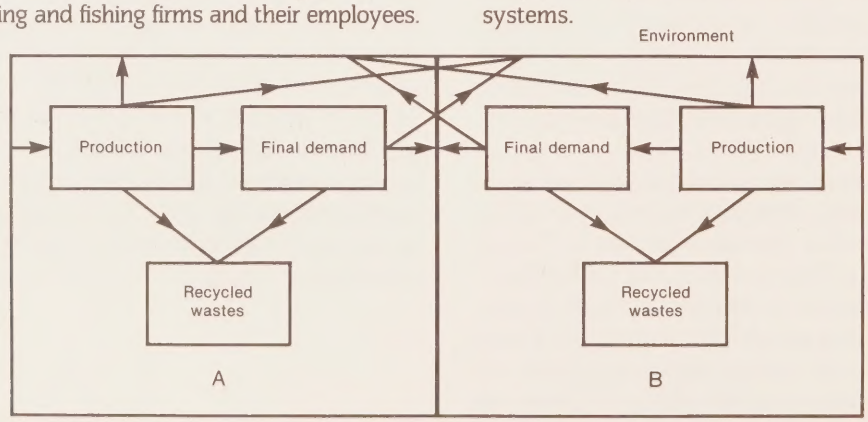

FIGURE 1
A Conceptual Materials Balance Model of Two Interrelated Economies

The sub-blocks A and B represent the materials balance for each region separately. The arrows between A and B indicate a mutual interdependence of A and B. This situation of externalities (non-market linkages), forms the background of most inter-regional and international environmental problems. The environmental quality of one part of a country or of the world is affected by the production systems of other regions or countries, although the regions or countries causing the effects are usually neither accountable nor charged for reducing environmental quality elsewhere.

In this set of interactions, there is no market system to clear the mutual damages. The interdependent system reveals the possibility of many frictions and conflicts among regions within the system.[1] A great variety of interests may exist both within and between regions or countries. These interests make it very difficult to achieve balanced economic development or consensus on environmental-economic policies.

The interdependencies of this model imply that areas, regions and countries of the world are mutually dependent. The raw material base, the growth of production, and the environmental quality of each area and region are co-determined by situations in other regions. Clearly, the economic demands and production processes of one region can increase environmental stresses in another, either directly through downstream or downwind effects, or indirectly by stimulating the creation of residuals in one region to meet the production demands of the other.

From the foregoing, it is apparent that the environmental quality of one region of Canada can be affected by the production demands of other regions. For example, some of the Ontario manufacturing sector pollution effects result from the demand for consumer products in other parts of the country. At the same time, the demands of the manufacturing sector in central Canada for raw material inputs cause environmental effects in regions far removed from Ontario.

The spatial effect is particularly relevant to the Canadian economy. With its emphasis on natural resource and primary industry activities, each demand for Canadian goods and services by foreign countries will produce environmental effects in some region of Canada. An example of this is the Japanese demand for coking coal and the environmental effects in British Columbia resulting from coal mining and waste disposal.

It is critical then, to appreciate that interconnections between environmental quality and economic activities, especially in the case of very large nature resource-based economies such as Canada's, involve both inter-regional and international linkages. The complexity of linkages and interrelationships between the environment and economic activity should not, however, discourage us from addressing them. Government, industry, and community leaders must formulate policies and take action to guide our collective behaviour in order to ensure the general welfare of Canadian society. In dealing with problems involving linkages and interrelated effects, it is important for the planner, adviser or policy-maker to fully appreciate the nature of the dynamic systems involved. A single dimensional analysis, calculation, or measurement of one factor, or of one set of factors, at one point in time, will not serve as a reliable basis for formulating policy or initiating action. The reasons for this include:

— Economic-environmental systems are dynamic and involve changing processes over time.

— Environmental-economic system variables combine and interact with each other in synergistic ways.

— The effects of economic activity on environmental quality vary spatially and over time, i.e., similar events produce different environmental and economic effects in different geographic areas, and will produce different effects at different times.

— The environmental effects and consequences of economic activities are not easily separated into discrete local, regional, national or international sets. A distant economic activity or event may cause economic and environmental effects at various levels elsewhere. For example, increased demand for aluminum in the U.S. will have economic and environmental implications both in Jamaica (bauxite mining) and in Canada (hydro-electric development projects and port construction).

While it may be difficult for laymen to appreciate all of the nuances of economic theory and principles, it is, in our opinion, important for all interested parties to have a basic understanding of the nature of the questions being investigated and the implications of various policy choices. As mentioned earlier, simple guidelines are not available, and there is no unanimity at the theoretical level. It is doubly important, therefore, for policy makers to be aware of the possible effects that can flow from particular actions or policies.

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1 The question of inter-regional and inter-area friction, and ways to deal with it are examined in the literature on multi-objective, multi-criteria analysis, regional decision-making, and negotiating-bargaining techniques. (See Dorcey A.H.J., 1984).

To gain this awareness, one must appreciate both the techniques and methodologies available to analyse the issues, and their limitations. Linkages between the economic system and the environment are complex and interrelated. To simplify (or worse, to ignore) the complexities and proceed on a non-empirical anecdotal basis, risks misunderstanding the dynamics occurring within the systems. Drawing conclusions based on partial analysis of the relationships can lead to recommending policies or actions that contribute negatively rather than positively to economic welfare and to environmental well-being.

The following chapter reviews and summarizes some of the theories posited, and the philosophical questions raised by analysts in investigating environment-economy relationships.

ECONOMIC THEORY AND THE MEASUREMENT OF ENVIRONMENT-ECONOMY RELATIONSHIPS

Introduction

It can be quickly appreciated that the whole question of economy-environment relationships, interactions, and their effects, will depend upon one's starting viewpoint. Any analysis of the subject or review of approaches to determine appropriate prescriptions for policy or action plans must, therefore, identify the paradigm or set of beliefs upon which the analysis rests.

Several theoretical views of the nature of the modern economy, its role in society, and its relationship to the natural environment, have been developed since the industrial revolution began. Each of these illustrates the effect of adopting different paradigms concerning the moral, ethical and material purpose of society. Three of these theoretical approaches are reviewed in this chapter to highlight the issues that must be addressed when considering environment-economy interactions. They are: neoclassical economic theory, thermodynamic economic theory, and evolutionary economic theory. A brief discussion of paradigms precedes this review to emphasize the importance of understanding the viewpoints or value systems on which various economic theories are based.

Paradigms

The perspective that one has of political economy (i.e., the organization of society's economic activities) will depend to a great extent on the paradigm under which one is operating. A paradigm is the set of views, preconceptions, or patterns of thought that form the lenses through which we see the world. Paradigms form the unconscious, tacitly shared perspectives that are necessary for experimentation and for accumulating a shared body of knowledge.

Scientists have, on occasion, been forced to re-examine, alter and periodically abandon paradigms upon which a whole set of scientific throught has been based. Three examples of abandoned paradigms follow: that man was created whole, unrelated to the rest of nature; that the earth is flat; and that the earth is the centre of the universe. Each of these paradigms served to explain reality to society for a period of time. Eventually, facts about the world became known, facts that could not be reconciled with the old paradigm, and a new perspective was adopted to better match reality. Much of society's rapid progress and development over the last 300 hundred years, after millennia of rather slow social evolution, may be attributed to the adoption of new paradigms.

The introduction of a new paradigm often constitutes a revolution, because it requires the adherents of these new ideas to abandon and perhaps turn in opposition to their intellectual community and many vested and powerful interests. A case in point was the introduction of the concept that no man should be the slave of another. The adoption of this concept eventually resulted in the American Civil War, and led to the abolition of slavery.

When a new paradigm is discontinuous with the preceding paradigm, it is often difficult for the new and the old adherents to relate to each other. This difficulty arises because some of the most basic issues and questions about the purpose and ultimate meaning of an action or condition will be perceived completely differently. For example, to a scientist familiar with micro-organisms, bacteria, and viruses, the conditions that lead to a child becoming stricken with diphtheria or polio are understandable and preventable. However, to a person unfamiliar with modern medicine, those conditions may be viewed as "acts of God". Similarly, perceptions about the nature of economic organization and the relationship of economic activity to man and the environment will differ depending on one's viewpoint.

All analyses of economic issues implicitly involve the adoption of a particular paradigm. Consider the following: Is economic growth a permanent "normal" process of a healthy economy, or is it a temporary phenomenon representing a stage between two levels of steady non-growth states? What satisfies an individual's wants — is it merely his wealth or income? Should we conceive of labour, land and capital as separate sources of value, or should we conceive of labour alone as the sole source of value? Are exhaustible natural resources "ordinary" inputs to the productive process, or are they a special category of inputs?

Questions such as these must be resolved before analysis can begin because identical analytical processes based on different paradigms will lead to different conclusions. This means that one must adopt a particular paradigm. It should be noted that the effect of different paradigms is not simply a matter of saying "there is always more than one way of looking at an issue". The adoption of a particular paradigm usually has implicit in it elements of personal belief, faith, or values which are not reducible to logical argument.

Economic thought during the last two centuries has experienced a number of paradigm shifts. These shifts are evidenced by the prevalence and decline of such notions as mercantilism, natural law, labour theory of value, the invisible hand of Adam Smith, and the dialectic between the classes as posited by Marx. Each paradigm yields a different understanding of the nature of man's economic activities, and of the proper, ethical or moral relationship of man to others and to his environment.

Neoclassical Economic Theory

The neoclassical economics school is derived from the works of Adam Smith, J.S. Mill, Léon Walras, Alfred Marshall, J.M. Keynes, V. Pareto, Paul Sammuelson, et al. The hallmark of this school of thought is its focus on satisfying the needs and wants of individual consumers through a process in which the individual's preferences and needs determine choices made in the marketplace. These individual choices, in total, are assumed to result in the best possible allocation of resources and materials in the economy. The ideal of "market equilibrium" is achieved when the marginal functions (cost, utility, revenue, etc.) are equal, and the welfare of all participants cannot be improved further without adversely affecting another's welfare.

Market prices in the "state of equilibrium" are assumed to represent optimal relative values, reflecting the needs, wants, and priorities of the individual consumer and of society as a whole. Competition, in the neoclassical system, provides the motivation among producers (for profits), workers (for wages), and capital (for rent). Such competition ensures, it is assumed, an efficient allocation of physical and human resources.

Substitution between raw material inputs, labour and/or capital will occur automatically, as efficiency factors (e.g., marginal costs of production, or productivity of labour) dictate, and as technological innovation permits.

Issues concerning future allocation of resources or choices are taken into account through the use of discount rates. These are used to estimate the "present value" of goods or services produced or foregone in the future.

Neoclassical economic theory assumes that the behaviour of individuals and society within an economy can be explained, predicted and measured through the use of a general equilibrium model. Through the use of generalized mathematical algorithms, this approach "explains" the behaviour and role played by consumers, firms, labour, savings, investment, and capital. Each of these factors is assumed to operate in markets according to varying degrees of competitiveness (e.g., perfect competition, oligopoly or monopoly). The economic actors are guided by preferences and tastes, marginal costs and benefits, utility considerations, future considerations (interest and discount rates), and the relative prices of goods and services.

Neoclassical Economics and the Environment

At the centre of neoclassical economic theory is the "sovereign consumer", who shows preferences in the marketplace by the prices he or she is willing to pay. The market is considered to be functioning when preferences of consumers are filled, and as failing when they are not. The economic significance or value of an action is based on the level of utility that an individual or society as a whole receives from the use of scarce resources, goods or services. Maximizing utility (satisfaction) is considered the appropriate economic goal of individuals and society as a whole.

In the neoclassical economy, the environment is simply a supplier of inputs to the production process of firms producing various goods and services. The economy consists of many such firms competing to satisfy the material needs of consumers. The economic system, theoretically, should have a tendency toward a state of equilibrium in which demand and supply, needs and wants, marginal costs and marginal revenues, etc., are equal. Equilibrium will occur once the marginal utility of acquiring additional goods and services and the marginal profit of producing them have been sufficiently reduced.

In practice, however, increases in population require new employment, additional consumer "satisfaction", and the promotion of a consumer ethic that encourages ever-increasing consumption of more and more trivial and non-essential products. Accordingly, a growing population hinders the achievement of this theoretical state of balance. In fact, the neoclassical model has become synonymous with the need for continuous growth of population, of production, of consumption, and of waste generation. Growth is justified as necessary to achieve the material demands generated by "sovereign consumers".

The continuous expansion of an economy is bound, eventually, to meet with difficulties such as space for its population, exhaustion of finite natural resources, waste disposal, and energy shortages. The neoclassical market economist takes the position that these problems will be resolved in the marketplace if it attaches sufficient value (price) to supplying a particular resource. If the market price is high enough, the incentive to either find and supply the resource, or to develop replacement products through technological innovation, will be sufficient to ensure that demand is met.

A major problem with neoclassical theory is its inability to take account of the effect on the economy of diminished supplies of finite non-renewable resources, except by assuming that substitutes will be found, or that new supplies will be discovered indefinitely. The only answer to this problem that neoclassical economics can offer is faith in technology.

The Common Property Resource Problem

A few goods, called common property resources (e.g., air and water), are assumed to have no price, since no markets for them exist. As a result, the contribution of these resources to human welfare is not explicitly accounted for in neoclassical economics. Since no property rights are associated with these resources and, therefore, no simple basis exists for assigning monetary values (prices) to them, producers are free to use them at little or no cost. Since the producers' goal of maximizing their profits can be achieved by reducing production costs, maximizing the use of "free" or low-cost resources will be the preferred strategy.

During extraction, harvesting, processing, and distribution, the market system allocates materials and energy reasonably well. Unfortunately, most residuals left over after consumption and processing are dispersed into the common property environment. Common property assets, such as the seas, wilderness areas and the atmosphere, do not enter a market exchange. They are progressively degraded because industry, governments, and individuals use them as cost-free dumps, even though other uses of these resources, such as fishing, recreation, or agriculture may be lost through the dumping actions.

It can be expected, therefore, that in a normal, competitive market economy, free or unpriced commodities will tend to be over-used. Overuse implies that there will be, over time, a predictable decline in common property resources (i.e., a large portion of the stock of environmental capital). These conditions have been appropriately described as "the tragedy of the commons".

Externalities

In order to cope with some of the non-market aspects of production and consumption, neoclassical economic theorists developed the concept of externalities. Externalities are the effects of actions by different individuals or firms — actions that are not accounted for in market transactions. Usually, external effects are of concern when the well-being of one firm or individual is affected by the actions of another, without payment of compensation for the damage. An example would be one firm discharging waste into a river, and a downstream firm having to incur costs to treat the water before it can be re-used. There are a variety of different types of externalities. A detailed description and listing can be found in Nijkamp (1977).

In order to include externalities in analytical models, and to internalize the cost of their effects, neoclassical theorists conceived the "compensation" idea. This idea is based on the assumption that environmental externalities (non-market changes in environmental quality) disturb the economic system's equilibrium. The theory suggests that one approach to returning a system to equilibrium is to pay compensation to an injured party, to the extent required to restore that party to his or her original state of economic well-being. While this notion has a certain "theoretical elegance", in a practical sense it has some very limiting assumptions that reduce its usefulness for solving environment-economy system problems (see Nijkamp 1980).

Summary Observations on Neoclassical Economic Theory Vis-à-Vis Environment-Economy Relationships

For economic theory to be useful in analysing environment-economy relationships and linkages, it must, in addition to describing market dynamics and the mechanisms of consumer satisfaction, recognize and incorporate the processes through which materials and energy are extracted from the environment, transformed, consumed and, eventually, returned to the environment as waste residuals. One of the reasons that market-oriented neoclassical theory encounters difficulty in dealing with environment-economy relationships is that it does not adequately value the materials and energy flows that occur between the environment and the market economy. Instead, it focuses on the value of production as derived from non-physical utility or satisfaction of consumers.

Serious criticisms have been made concerning the premise that maximizing consumer utility or satisfaction yields optimal welfare for the society as a whole. Research by Scitovsky (1976) found no evidence that the level of human well-being grows proportionately to increases in the quantity of priced commodities in an economy. Some industrialized economies, it has been suggested, may have already reached a satisfaction "saturation point". These economies may actually be experiencing a decline in "quality of life" as perceived by individual citizens. This perception is reinforced when the physical quality of the environment also appears to be declining.

Hirsch (1976) suggests that limits to growth of production in modern economies are not based solely on physical constraints (resource supply, population, etc.), but stem as well from non-market effects such as stress, long-lasting illness, and dissatisfaction with working conditions. The conclusion by Nijkamp (1980) is that the well-being of human society and the individual is a multi-dimensional variable composed of several elements such as income, environmental quality, distribution of political power, and quality of working life. This concept suggests that measures of utility and the wants of the individual in the economic-environmental system have neither been adequately understood nor properly incorporated into neoclassical economic throught.

Thermodynamic Economic Theory

Thermodynamic economic theory links economic, technological and ecological processes. While neoclassical theory portrays the economic system as a closed, circular flow of monetarized values, theories based on thermodynamic laws hold that such a circular flow does not exist for material products and energy. This view suggests that economic activities are linked to, and exert claims on the environment — i.e., the input sector makes demands on the resource base of the economy, and the output sector introduces residuals from the economy into the environment. The first leads ultimately to the exhaustion of non-renewable natural resources; the second to pollution and environmental degradation.

Materials and Energy Flows and Balances

Materials and energy flows and their relationship to economic activity have been described and elaborated by several authors including Ayres, Kneese et al. (1969), Freeman et al. (1973), Kneese (1977), Nijkamp (1970, 1980), Owen (1984), Senaca et al. (1974), Victor (1972), Bower (1979) and Lakshamanan et al. (1980). Schematic models are illustrated in Figures 2 and 3.

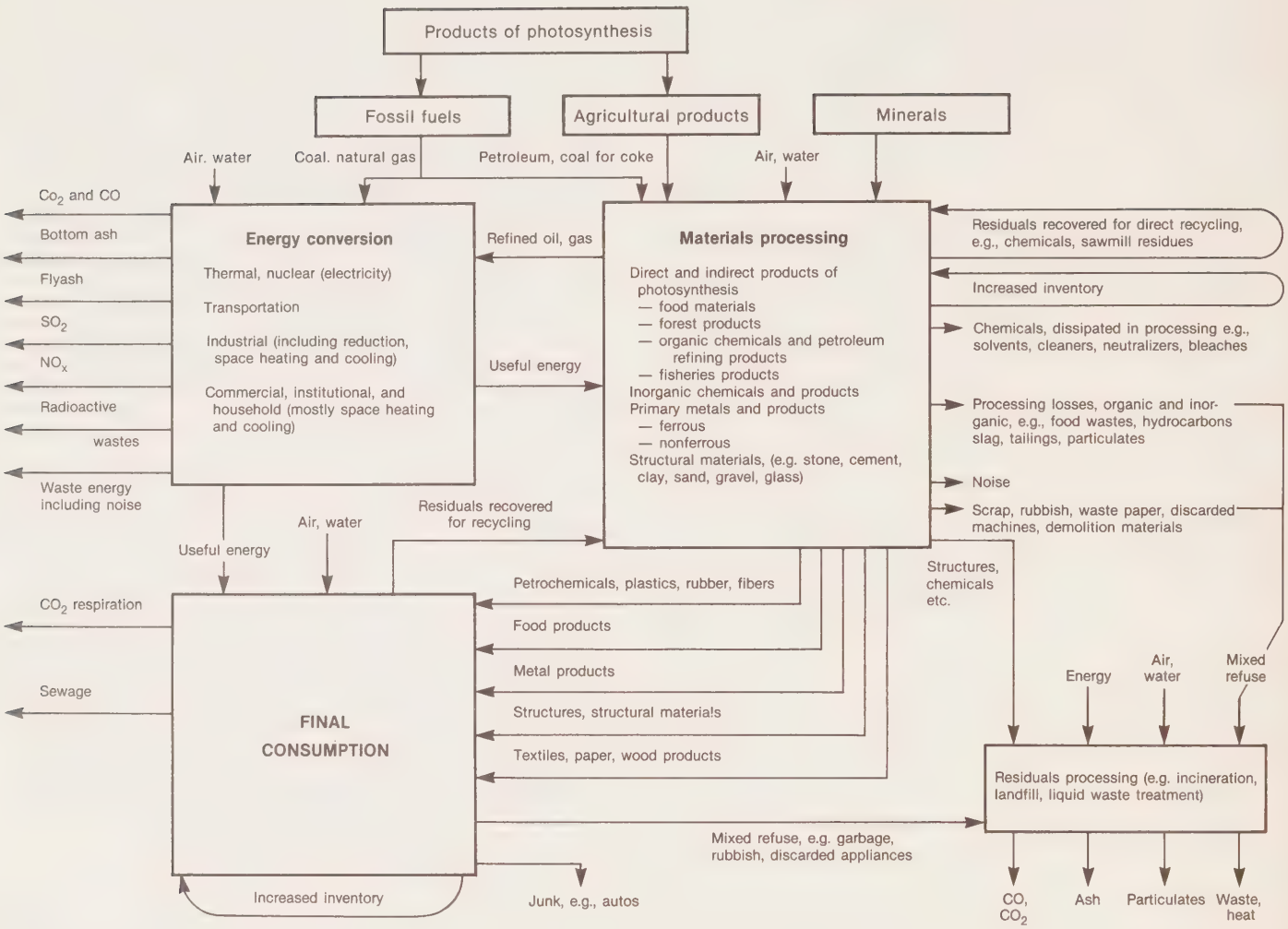

FIGURE 2
Materials and Energy Flows in Society
Modified from Resources for the Future, 1969 Annual Report, (Washington, D.C., R.F.F.) p. 26.

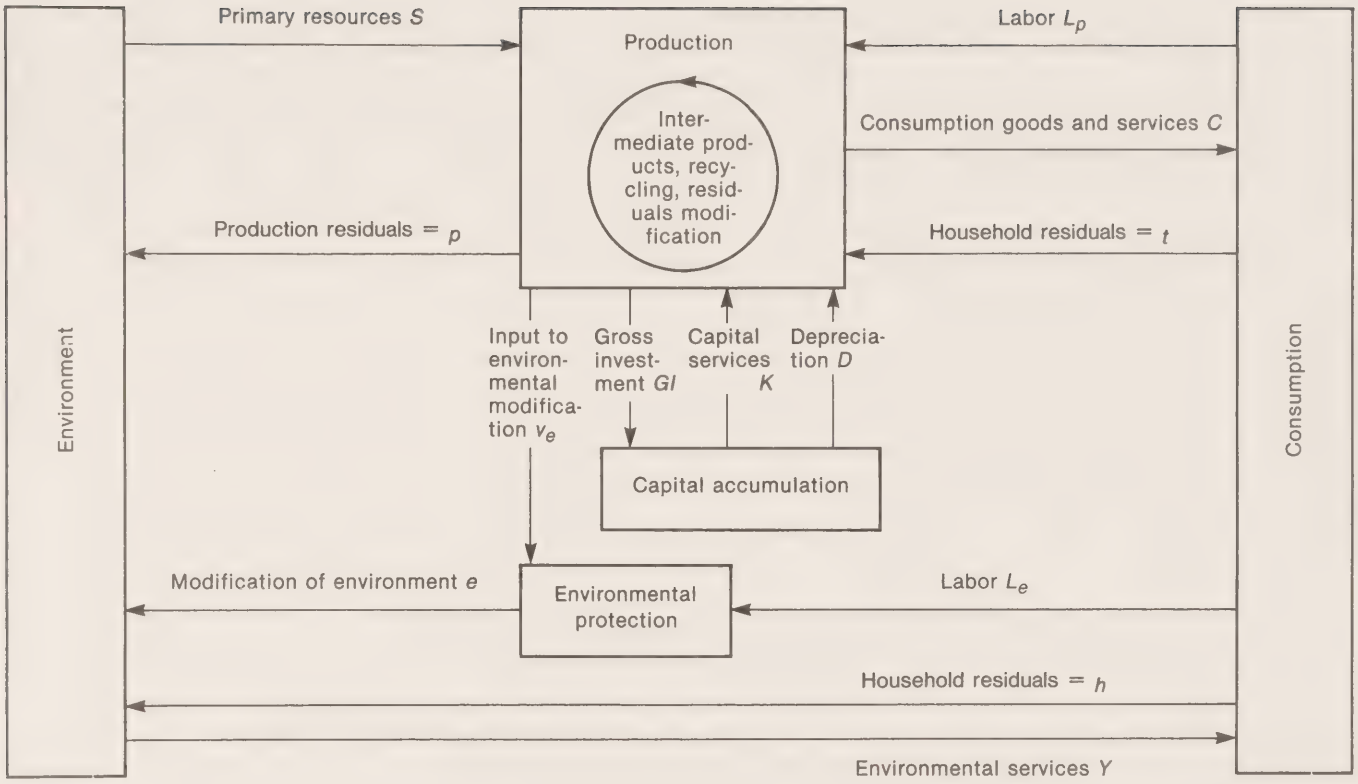

FIGURE 3
Model of the Flows of Materials
(From Kneese and Bower, 1979)

The concept of mass-energy balance is based on the first law of thermodynamics, otherwise known as the law of conservation of matter. Broadly stated this law holds that in spite of numerous transformation processes, no matter is created or destroyed in the course of extraction, production and consumption. Apart from transformations into energy, there is a physical balance between inputs and outputs in all transformation processes of a given system.

It can be deduced from this law of physics that each increase in the level of production of material goods in an economy will lead to:

— a corresponding increase in the requirement for natural inputs and energy from the environment; and

— a corresponding increase in the waste load on the absorptive capacity of the environment.

The neoclassical market economy treats common property resources as free and most raw materials as having relatively low per-unit values. As material and energy move from the environment through the economy in progressively more highly processed forms economic value tends to increase continuously. This increase in value occurs until the materials and products are "used up" or "worn out", and then returned to the environment as worthless residuals.

In the neoclassical economy, the value the system attaches to the inputs, as they are transformed, is derived from the utility the resulting products yield at a particular time to consumers. To continue to supply large quantities of high-utility, satisfaction-yielding products, the economic process must continuously expand the flow of raw inputs into the transformation process.

It is clear that a neoclassical market economy is likely to require permanent growth to achieve the objective of meeting continuously expanding consumer demand. Meeting this objective necessitates increasing the demand on the environment to absorb the resulting wastes. It can also be seen that the indestructible nature of matter constitutes a major obstacle to man's seemingly unquenchable desire to transform the natural environment into consumable products.

The problem of disposing of waste outputs is, in itself, very serious. However, it may not constitute the most serious limit to growth that faces modern industrial economies. The second law of thermodynamics (the entropy law) may be even more critical.

Entropy and the Economic Process

The classic depiction of economic activity as a circular process that can be understood as a self-sustaining mechanical system has serious deficiencies. It seems to deny that economic processes are directly related to the natural physical environment and dependent on it.

The first law of thermodynamics establishes that matter and energy cannot be created or destroyed. If this is the case, then just what does the economic process do? From a physical point of view, the economic process absorbs matter-energy and throws it out continuously. Some economists, such as Nicholas Georgescu-Roegen, would say that what goes into the economic process represents valuable natural resources, and what is thrown out is useless waste. From the viewpoint of the laws of thermodynamics, matter-energy enters the economic process in a state of "low entropy" and exits in a state of "high entropy".

The entropy law implies that matter and energy are found in two forms. The first is organized, structured, and ordered matter-energy that can be used or transformed into work or energy. This matter is called free or available energy. A lump of coal prior to burning contains available energy and is said to be in a state of "low entropy". However, when the lump of coal is burned it is transformed into an unorganized, chaotic form (dissipated heat and ash) that has no available energy and it is described as being in a state of "high entropy". This material cannot be further transformed by man into work or energy. As material-energy moves from low entropy to high entropy forms, its value for use by man is reduced or eliminated.

All matter-energy is involved in a process of moving from low to high entropy. Economic processes do not create this movement. It happens inexorably in nature, and man simply accelerates the rate of the entropic process. In a closed system, this process is irreversible. Only the introduction of additional low entropy energy from outside a closed system, such as energy from the sun, will permit reverses of the entropic process. Renewable resources (plant and other organic life) have an ability to achieve and maintain a constant state of entropy by capturing and converting low entropy energy of the sun. However, in order to achieve even a constant state, an organism must consume some low entropy energy from the soil or other source as well.

The implication of the entropic process for man's future, according to some theorists, is dramatic. The difference between non-renewable natural resources and renewable organic resources is the ability of the latter to renew themselves by capturing the sun's low entropy energy. Because these organic resources transform "free" low entropy from the sun, their supply is more dependable and long-term than the finite supply of low entropy mineral resources and fossil fuels.

The implications of the entropy laws are far-reaching. Since man's economic struggle centres upon using environmental low entropy material, the supply of this low entropy material is critical to the future of modern society. The *stock* of free energy of the earth is found in concentrated mineral deposits; the *flow* of free energy comes from the universe in the form of radiation, mostly from the sun.

"While economists are fond of saying we cannot get something for nothing, the entropy law teaches us that physical laws are far harsher. In entropy terms, the cost of any biological or economic enterprise is always greater than the product. In entropy terms, any such activity necessarily results in a deficit." (Georgescu-Roegen, 1971).

The dramatic growth of the industrial economy during the last 200 years has been fueled by low entropy, non-renewable resources (minerals and fossil fuels). This growth has been achieved, on the one hand, by developing the technologies to exploit these non-renewable resources, and on the other hand, by applying mechanized, capital intensive practices to harvesting our renewable resources. As a result, our dependence on the finite supply of non-renewable resources (particularly fossil fuels) has increased dramatically. At the same time, our renewable resources have been degraded despite their potential to capture the almost unlimited flow of energy from the sun.

The degree to which one should be concerned about the entropic nature of economic activity depends upon the stock of low entropy material at one's disposal, the time horizon one cares about, and the degree to which one believes that technological innovation will alter the transformation process and thereby forestall the exhaustion of scarce low entropy resources. It also depends on the degree to which one is concerned about the quality of life of future generations. This latter issue raises ethical and moral questions that neoclassical theorists have managed to avoid, but which others hold are unavoidable.

In view of the finite stock of low entropy non-renewable natural resources, the rate of degradation of organic natural resources, the global population growth rate, the consequent demand for ever-increasing inputs and processed products, and the resulting increase in waste outputs, there are reasons to be concerned that the vast stocks of terrestrial low entropy resources available to man may not be sufficient to sustain modern economic development for extended periods, e.g., another century. To sustain the present rate of economic activity, some of the variables such as population growth, rates of waste disposal into the air and water, and excessive production of non-essential consumer convenience products may have to be altered.

The adverse effect of continuous population growth has been clearly identified by many governments in lesser-developed nations. Industrialized nations have been slower to develop concern about global population growth. Technological advances in the industrialized countries have created an impression that innovation will always be capable of "fixing" the problem and that it thereby will allow society to avoid all unpleasant consequences of the entropy process.

In summary, thermodynamic theory states that the consequences of economic development involve use of low entropy matter-energy which cannot be re-used for alternative benefit. Therefore, the use of this matter-energy represents a loss of opportunity for future use. "Economic development through industrial abundance may be a blessing for us now and for those who are able to enjoy it in the near future, but it is definitely against the interest of the human species as a whole, if its interest is to have a lifespan as long as is compatible with dowry of low entropy." (Georgescu-Roegen, 1971).

What are the appropriate responses to the choices presented by the issues raised by "thermodynamic" theorists? Should man pursue goals of immediate material satisfaction and let the future take care of itself through "market adjustments", as neoclassical economic theory suggests? Or should he have a biological concern for the fate of the human species as a whole and adopt a pattern of economic activity that husbands low entropy resources for future use? Is industrial society hopelessly and irrevocably dependent on scarce non-renewable low entropy for life support, and at the same time hopelessly addicted to industrial luxuries?

The foregoing questions lead our analysis toward a larger set of moral and ethical questions which, in terms of assessing the nature and impact of economy-environment relationships, may lie at the heart of the matter. While one might prefer to avoid such considerations, the notion that these problems can be dealt with in a mechanistic manner simply by assuming that "market forces" will somehow resolve them, could be a form of self-selusion.

Georgescu-Roegen's main contribution, in focusing upon the entropy problem (1966, 1971, 1979, 1981), may well be that he has forced a rethinking and reconsideration of the purpose and nature of modern economic activity. Is it simply a process that transforms valuable natural resources into low value waste, or is it a process, as he suggests, the objective of which is not simply a flow of waste, but an immaterial flux: the enjoyment of life?

This suggestion raises philosophical questions concerning how economic activity should be organized: whether according to technological possibilities and unending production of non-essential material consumption — or according to a more complex set of objectives, including the interest of future generations, the balanced co-existence of all life forms, and the spiritual as well as material satisfaction of society.

These latter questions have been raised over the last century by a number of authors, including Adam Smith, J.S. Mills, T. Malthus, F. Soddy, K. Boulding, J.K. Galbraith, E.F. Schumacher, N. Georgescu-Roegen, H. Daly, J. Rifken and others. Many have to some degree alluded to the possibility of a stationary or steady-state economy.

Thermodynamics and the Steady-state Economy

The concept of the steady-state economy has been championed most energetically by Herman Daly (1973, 1979). It is an approach to understanding economic-environmental interac-

tion that is based upon the thermodynamic laws of conservation of matter and entropy. It incorporates in its paradigm the idea that "nature really does impose an inescapable general scarcity on man's economic activity" (Daly 1979) and that it is a serious delusion to believe otherwise.

The steady-state concept runs counter to neoclassical thought, which insists that man's technological advances have freed him from dependence upon the natural environment and, according to Robert Solow, that "thanks to the productivity of natural resources, increasing more or less exponentially over time, the world can, in effect, get along without natural resources" (Solow 1974).

Thermodynamic economic theory, on the contrary, insists that "life derives the whole of its physical energy or power, not from anything self-contained in living matter, and still less from an external deity, but solely from the inanimate world. It is dependent for all necessities of its physical continuance primarily upon the principles of the steam engine (thermodynamics). The principles and ethics of human convention must not run counter to those of thermodynamics" (Soddy 1922).

Modern economic theory defines economics as the study of the allocation of scarce means among competing ends. Those authors and theorists who criticize neoclassical precepts and paradigms have insisted we must re-examine and reconsider both the ends and the means involved in the economic process.

Daly (1979) argues that neoclassical economists' "excessive devotion to growth is a result of an incomplete view of the total spectrum of man's means and ends". This spectrum is conceived as depicted in Figure 4. At the top of the spectrum is the "ultimate end", something intrinsically good that is not derived from any higher good. At the bottom of the spectrum are the "ultimate means" available to man (low entropy matter-energy). Each intermediate category is an end to categories lower than itself, and a means to higher ends above itself. These intermediate ends and means are ranked in order, up to the ultimate end. Traditional disciplines of study related to a variety of these ends and means are listed beside the spectrum.

According to this view, traditional economic thought has concentrated only upon a portion of the spectrum. Absolute limits are absent from the growth economist's paradigm, because absolutes are only encountered at the poles of the spectrum. Ethics and technics only exist at the periphery of the area being examined. By concentrating only on intermediate means to meet intermediate ends, "the growth economist's vision is one of continuous growth in intermediate means (unconstrained by any scarcity of ultimate means) in order to satisfy ever more intermediate ends (unconstrained by any impositions from the ultimate end)" (Daly 1979).

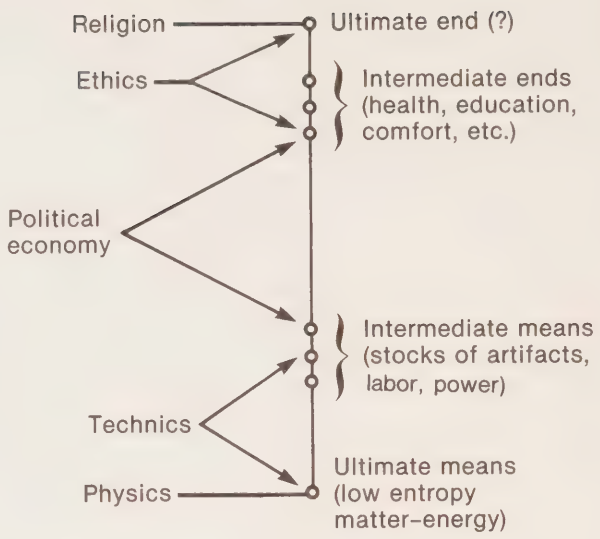

FIGURE 4
Spectrum of Ends and Means

Daly argues further that when one considers the poles of the spectrum, a different perspective emerges. In his opinion, this perspective forces two important questions:

— *What precisely are our ultimate means, and are they limited in any way that cannot be overcome by technology?*

— *What is the nature of the "Ultimate End"? Is there a point beyond which further accumulation of intermediate means not only fails to serve the Ultimate End, but has a negative effect in terms of achieving the Ultimate End?*

The answer to the first question, for the thermodynamic theorist, is "yes", as already given earlier. The laws of conservation of matter and the entropy laws constrain the "Ultimate Means" at our disposal. As technology increases order in one part of the universe, it creates an even greater amount of disorder elsewhere. If the elsewhere is on the sun, then perhaps we need not worry. If it is on earth, then we must pay attention.

"The throughput flow maintains or increases the order [low entropy] within the human economy, but at the cost of creating greater disorder in the rest of the natural world, as a result of depletion and pollution" (Daly 1979). There are, according to ecologists and other physical scientists, limits on how much disorder can be produced in the rest of the biosphere, while still allowing it to function well enough to continue supporting the human sub-system.

The thermodynamic theorists have suggested that our goal should be an economy in which technological development operates in recognition, and in accommodation with, the basic physical limits of all matter-energy. This goal, they say, would imply a non-growth, steady-state economic system.

The second question is one that modern economists have avoided assiduously. Ethics have been reduced and personalized down to individual choice, and questions of moral right or wrong have been ignored in the general equilibrium model of modern neoclassical theory. As much as we may want to avoid thinking about it, the question, "What is the 'Ultimate End' or purpose of our economic actions?", will not go away.

Subsidiary questions to this primary question include: Should we explicitly, in our statement of economic purpose, acknowledge respect for the evolutionary process? ...for the gift of self-conscious life? Should survival of the biosphere and its evolving processes be a stated priority? To what extent should evolution be influenced by man, and to what extent should it be left to occur spontaneously? Should present-day trivial wants and needs take precedence over future basic needs?

In addition to this line of thought, questions concerning the nature of material satisfaction and utility, which are the cornerstones of neoclassical theory, are unavoidable. Is there such a thing as "enough" in the material realm, and is enough better than more than enough? What is the purpose of unending growth if it doesn't even satisfy one of the most powerful of individual consumer motivations — that of status or distinction within society?

"When society has reached a level of affluence such that, at the margin, the relative wants of distinction are dominant, then aggregate growth becomes either futile, or the source of increasing inequality." (Daly 1974) At some point, according to this argument, growth becomes undesirable, even if still possible.

Awareness of the laws of diminishing marginal returns, which affect benefits and costs, combined with solid evidence that absolute scarcity of natural resources is real, should be enough to convince us that it is time to think about growth as a means to some end, rather than as an end in itself. "The fact that growth-induced disruptions of environmental services cannot be organized to occur in increasing order of magnitude is a major obstacle to economic calculation and suggests that a goal of "satisficing" rather than maximizing may be preferred" (Daly 1974).

This analysis led Daly and others toward the concept of a steady state economy that would attempt to consciously maintain some of the key flow and stock variables in the economy constant, or in a "steady state".

The steady-state economy has four main features:

— *a constant human population (births = deaths);*

— *a constant stock of capital equipment and tools (production just replaces worn and depreciated capital);*

— *the levels of the human population and stocks of capital equipment are sufficient to ensure a good life for a long period; and*

— *the rate at which matter-energy is used is maintained at as low a level as is feasible.*

In the steady-state economy the behaviour of the individual and society is characterized by: (1) *stocks* are "satisficed", that is, just enough are produced to ensure a good and abundant life; (2) *services* received from goods, others, and the environment are maximized; and (3) *throughput* is minimized given the constant stock (1). The steady-state theory considers *growth* as an increase in services received from increases in stock and throughput. *Development,* on the other hand, is defined as increases in efficiency ratios (services/stocks), with stocks remaining constant.

Evolutionary Economics — A New Synthesis

For many years, one of the most honoured and distinguished social scientists of this century has, in his writings, sought to expand understanding of the problems of political economy and social welfare. During his career, Kenneth Boulding has been a non-conventional economic thinker who has inspired both Georgescu-Roegen and Daly. In his recent book, "Evolutionary Economics", Boulding has woven the threads of the issues described above into a larger construct, whereby economics and economic process are seen as extensions and reflections of the complex evolutionary process which dominates the living world.

"Economic life is a subset and a fairly large one at that, of total human activity in history. We should expect it therefore to follow general principles which govern the evolution of humans and human society. We can think of economic goods, therefore, as part of the general ecosystem of the world. Any good with an existing stock clearly has a niche of some sort, however temporary. Then ecological interaction provides a selective mechanism" (Boulding). Attitudes of humans toward these goods will have a powerful effect in determining whether a niche for a good will remain in the system.

Accordingly, by analogy to biological evolution, mutation in economic goods consists of the invention of new ones. Some goods survive if they find a niche; others do not survive. In the case of economic goods, the ecological interaction is mediated strongly through the price system. However, some features of economics such as interest rates, unemployment, labour markets, and inflation have no counterpart in the biosphere.

Boulding feels that the evolutionary perspective can be extremely illuminating in explaining the ongoing processes of economic life and the nature of the political and social environment.

"Economics has rested too long on the essentially Newtonian paradigm of mechanical equilibrium and mechanical dynamics."[2] Boulding feels that beginning with Adam Smith, Thomas Malthus, and Alfred Marshall, an evolutionary approach was suggested. It was only when the mathematical orientation of Walras and his successors began to dominate economic literature that the evolutionary insight was lost. In fact, it was early economic thinking that stimulated Darwin concerning human evolution (Adam Smith and Thomas Malthus).

Boulding reviews virtually every question posed by conventional economic theory concerning price mechanisms, interest, labour value, production functions, growth equilibrium, entropy and the steady state, etc. He very persuasively posits a theory according to which economic activity is analogous to dynamic biological processes in which complex organisms, with their inherited genetic characteristics, grow, expand, age, mutate, reproduce, and evolve.

The mathematical mechanisms of the neoclassicists, and the limiting laws of nature held up so forcefully by Georgescu-Roegen et al., are not denied, but incorporated into an elegant and convincing parallel to the biological world.

The new paradigm that Boulding presents is worthy of thorough review and consideration. It appears to offer a way out of the narrow intellectual cul-de-sacs of both traditional neoclassical and so-called "radical" thermo-dynamic economic theory. Its logic may provide a basis upon which a more adequate and sophisticated analytical base can be developed to understand and explain the complex nature of economic and environmental interactions.

Conclusion

The foregoing review of economic thought and its theoretical foundations, principles and paradigms serves to highlight just how deep and treacherous are the waters of environment-economy relationships. The nature of man's political and economic organizations, the nature of the physical world, and the moral and ethical paradigms being adopted, are all elements determining these relationships. If one attempts to deal partially or with only a selection of these elements, ignoring others, one is deluding oneself and will certainly derive answers that will not prove adequate, and may be quite contrary to society's interests.

The necessity of dealing with all these elements does not mean that it is impossible to proceed. It means only that analysts, policy advisers, and decision-makers must not shrink from the larger general questions, of which a specific problem is only a sub-set. Since our society has tended to avoid such questions, this requirement may at first seem awkward and novel. However, its value is undeniable. Unless we can test our analysis and policy proposals against the larger questions of society's broader long-term purpose, and against ethical and moral principles to which the society supposedly adheres, we are bound to cause our patterns of economic activity to follow irrational and erratic paths in terms of society's well-being.

Economic analysis is not simply an exercise in quantification and mathematical calculation. It is the exercise of defining the nature and purpose of social organizations, political economy, and human welfare. The array of factual information, technical data, and econometric technique will not yield insight unless the investigator understands what his purpose is and why he is examining the question.

While this review is not by any means a comprehensive treatment of all relevant issues, it serves to reveal the importance of additional effort, by all those individuals and institutions involved, in analysing and formulating environment-economy policy. It would be irresponsible and dangerous to leave the fundamental bases, assumptions and paradigms, upon which policy is formulated, to be debated among only a few theorists — theorists who have often succeeded in obscuring the most important issues rather than illuminating them. The future of modern industrial economies may well depend upon more enlightened participation of informed leaders and citizenry to guide their actions in this respect.

The following section proposes an analytical framework which should prove useful when considering specific environment-economy issues.

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2 Boulding, K.E., Evolutionary Economics, (California 1982), p. 17.

AN ANALYTICAL APPROACH FOR ASSESSING ENVIRONMENT-ECONOMY INTERDEPENDENCIES

Introduction

The review of economic theory and concepts in the preceding chapter identified some of the limitations of the traditional neo-classical economic approach in analysing economy-environment relationships. There is obviously a need to adopt a more complete analytical approach that accounts for materials flow, residuals, externalities, consumer preferences, and other effects arising from the linkages between ecological systems and economic systems at different spatial levels. There is also a need to integrate environmental and economic aspects so that a comprehensive picture of the effects of alternative policies and actions can be developed.

In the last decade, research into a more comprehensive analytical approach has been accelerating. A growing body of scientists, engineers, economists, environmental planners, and others have collaborated to better define the dynamics of environmental-economic social activities at different levels (regional, national, and international). The primary technique for conducting these analyses has been the use of models. Some of the models are conceptual, while others are operational representations of real economies. They have been developed with the hope of improving the quality of environmental-economic-social decision-making.

The object of much of this recent research has been to estimate the consequences of a particular set of policies on the level of consumption and output of goods and services, and on pollution emissions and other aspects of environmental quality. These consequences, calculated through a process of estimating and valuation techniques, provide a measure of the societal benefits which result. This modelling process, when repeated for various assumptions regarding policies and future states of technology or resource supply, can be used to compare policies or action plans, and can provide a basis for choosing the most desirable alternative.

In the last several years, a number of economy-environment-energy models have been built around this framework at national and regional levels. These models, given the complexities they encompass, are necessarily elaborate and combine elements of methodologies from many disciplines. Some models reflect the cooperative endeavours of social scientists, engineers, and physical scientists, and use a combination of techniques such as econometrics, optimization, and physical processes. The result, despite various limitations, is increasing ability to assess complex aspects of economic-environmental interaction.

It should be noted that no model can be all-encompassing when dealing with such a vast array of variables and interactions. For this reason analysts often chose to focus their efforts on specific relationships, specific spatial areas, or on specific time frames (e.g., the long-run or short-run). Efforts are now being made, especially in the U.S., to link various sub-models to better describe the overall systems and how they work.

Co-operation in these efforts is international, particularly between North American and European academics, scientists and policy makers. In 1980, a conference was held at the Netherlands Institute for Advanced Studies in the Humanities and Social Sciences (NIAS). The purpose of the conference was to discuss modeling research and policy analysis as they apply to economy-environment-energy system interactions. A brief review of the research techniques discussed, and of some developed since this conference, indicates the range of analytical tools currently available, and serves to highlight some of the limitations and obstacles that occur when one attempts to define or quantify these complex relationships.

The following analytical techniques were reviewed and are summarized in Annex 1:

— *Input-Output Analysis*

— *Materials Balance and Ecological Systems Models*

— *Integrated Environmental Impact Analysis*

— *Integrated Environmental Modelling*

— *Cost-Benefit Analysis*

— *Multi-regional Economic-Environmental Models*

— *Multi-layer Projection Model*

A Systematic Approach to Economic and Environmental Policy Making

The review of analytical techniques revealed clearly that no single formula or set of equations provides an easy or simple method to determine the "right" or "correct" action or policy for specific economy-environment questions. Each technique developed thus far has limitations in its scope or ability to adequately quantify and relate relevant factors. None of the quantitative techniques can, of course, answer the qualitative questions raised in Chapter 2.

It is, however, possible to develop an analytical approach that will both allow policy analysts, planners and decision makers to better understand the complexity of the problem, and enable them to further appreciate some implications of various policy and action alternatives. Such an analytical approach should require the investigator to deal rigorously, in

an organized sequence, with the subjective (qualitative) aspects, the theoretical aspects, and the technical (quantitative) aspects of the problems or questions being considered. Further, it should also provide some methodology whereby these aspects can be synthesized to ultimately form the basis for policies and actions.

Fortunately, a substantial amount of research has been completed on problem-solving systems and approaches (systems analysis). Therefore, establishing a conceptual framework is reasonably straightforward. If the exercise ultimately includes an analysis of the impact of actions, then the analytical approach should include the following principal components: [3]

1. *A description of the problem setting:*

   The set of physical, technical and institutional systems which constitute the problem setting.

2. *A set of policy or action alternatives:*

   These describe the assessment framework.

3. *An analytical model (or set of models):*

   These models in some form emulate the interactions of variables in the problem setting.

4. *A data structure or data set:*

   This set describes the characteristics of the variables and component systems incorporated in the analytical model.

5. *A set of evaluation criteria:*

   These criteria establish the basis for measuring the system's performance.

   The preceding components are essential to all impact analyses, and should be included in any systematic approach to considering economic and environmental system interactions. Figure 5 depicts schematically an approach to analysing the impact of particular policies or actions on the environment and the economy. It can be seen that the principal components are organized in a sequence that provides for an iterative analysis incorporating modelled information, policy alternatives, and evaluation criteria. Briefly, the principal components of this schema are:

Problem Definition: The definitive sequence for any problem-solving system requires a first effort to describe the problem. In most complex cases, this effort becomes an interdisciplinary undertaking aimed at providing information describing the "systems" that affect the defined or stated problem. Understanding and describing the problem environment are essential to developing a proper analytical procedure for assessing policy impacts. This step provides the basic framework for developing more elaborate modelling and analysis.

Policy or Action: With the physical, technical, economic and institutional environments described, the policy or action alternatives to be analysed must also be defined. These alternatives are analysed to determine the location and level of interaction with each of the previously defined physical systems. For example, a water development policy might result in an increased water supply. A water conservation policy might achieve the same goals through providing cost-reducing incentives to encourage adoption of more efficient technologies. This step must be thorough, since many initiatives interact to provide complex alternative sets of conditions.

Analytical Model: The development of analytical models is assumed to incorporate, in mathematical or other form, both a theoretical and methodological knowledge of the problem and its environment, and a knowledge of the alternatives being considered. The model may take many forms — from simulation to optimization, to a simple enumeration of alternatives. In cases involving economic analysis, it is assumed that relevant economic theory is incorporated. The analyst must consider feasible solution procedures when developing the analytical models. The previous review of economic theories indicates that contrary viewpoints on fundamental economic principles could well result in quite different conclusions being rendered from this exercise, depending upon the theoretical basis adopted.

Data and Information Base: The database is the most important item in developing systems that examine policy alternatives on a regional basis. To adequately define the physical, technical, ecological, and economic complex within which an analysis takes place, data must enumerate, so far as possible, the technical alternatives, resource variability and availability, and the interrelationships between them. This process must be consistent, flexible and timely.

The purpose of the analysis and the analytical modelling techniques chosen will largely define the data and information base requirements. It is not desirable to have the database structure or data availability dictate the analytical approach because in some cases, inappropriate aggregation of data can defeat the purpose of the analysis. Avoiding such aggregation is of particular importance in regional studies where it is essential to separate information into observable sets that describe regional factors, as opposed to national factors.

Evaluation Criteria: The results predicted by the model of the policy options under consideration should be compared using appropriate, consistent and explicit criteria.

[3] Adapted from Rinaldi and J.C. Wade (1981)

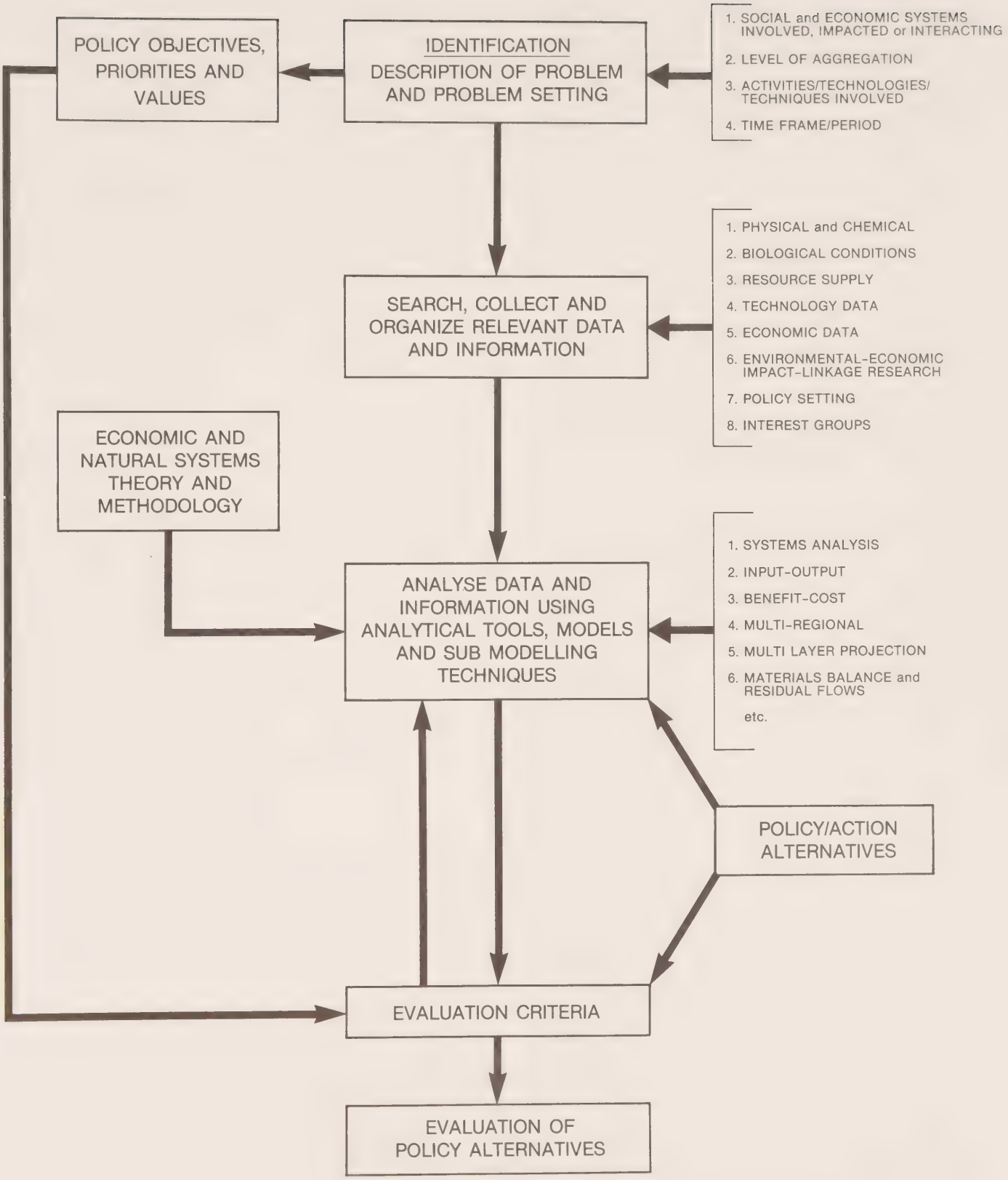


FIGURE 5
A Schematic Diagram Identifying Principal Components of a Systematic Impact Analysis

Application of the Integrated Approach

Efforts to address environmental-economic problems will be more efficient and productive if a systematic approach is adopted to organize the objective, the data required, the methodology to be used, the policy or actions to be considered, and the criteria by which alternatives are to be judged. The use of an approach as described in Figure 5 should assist in the assessment of what have been termed "wicked" problems (see Rittel and Webber 1973). This term acknowledges the difficulty of solving problems characterized by pervasive complexity and uncertainty.

By adopting and applying the integrated approach, the questions are dealt with in a sequence and hierarchy that allow one to better appreciate the core of the problem, issue, or question at hand. This approach also makes it possible to identify just where, in the problem solving sequence, each task fits, and where there are interdependencies within the analysis. It is clear, for example, that a search for data cannot proceed unless one has defined the problem and the problem set.

The following elements have been identified as necessary to begin an analysis of real current issues.

Problem Definition

The problem statement should, to the extent possible, indicate the following:

1. *The systems involved:*

   — social
   — political
   — environmental
   — economic

2. The level of aggregation of the analysis:

   — international/global
   — national
   — regional
   — provincial
   — local

3. *The technology or activity involved:*

   — modification of natural regimes
   — land transformation/construction
   — resource extraction
   — processing
   — transport traffic changes
   — waste replacement or treatment
   — recreation
   — accidents
   — etc.

4. *The time frame of the analysis:*

   — past
   — present
   — future (short-term)
   — future (long-term)

Once the problem set has been defined and described, possibly with the involvement of multidisciplinary expertise and some of the parties affected by the question, it is possible to proceed to search, collect, organize and assess the data and information readily available. The data required will, of course, depend on the methodology chosen. Therefore, methodology must be considered at this time. It should be noted that adequate data to analyse these problems is often not available, so that a major data collection effort becomes necessary.

Data and Information Search

It is suggested that data and information relevant to environment-economy questions and issues should be subdivided into a number of distinct categories. This set of categories could include the following:

1. *Physical Characteristics:*

   — earth
   — water
   — atmosphere
   — processes

2. *Biological Systems:*

   — flora
   — fauna

3. *Resource Supply* — land use estimates, potential and variability data

4. *Activities and Related Technologies*

5. *Economic Data* (costs, values, production data, etc.) for:

   Primary Industries:
   — agriculture
   — forestry
   — fishing, hunting, trapping
   — mines, quarries, oil wells

   Secondary Industries:
   — manufacturing
   — construction
   — electrical power, other utilities

Tertiary/Service Industries:
- transportation
- communications
- wholesale and retail trade
- finance, insurance, real estate
- business and personal services
- travel and advertising

Public Sector:
- expenditures
- revenues

6. *Demographic Data (Census)*

7. *Related Studies and Research:*
   - case studies
   - impact assessments
   - analytical models

8. *Policy Setting (Existing):*
   - related legislation
   - regulations
   - rules
   - jurisdictional definitions

9. *Interest Groups and Affected Population:*
   - surveys
   - polls
   - research
   - representations, briefs and litigation

Grouping data according to the categories suggested, or in some similar fashion, should allow for ready identification of data gaps and incomplete information. At this stage, a major decision must be made on the costs of undertaking additional data collection, the extent of further data collection, and the type of data required. Inherent in this decision is a judgement about the consequences (cost) of not collecting the data, not completing the analysis, and not taking informed policy actions.

This is not to say that efficient and cost-saving alternatives should not be considered. Depending on the question involved, innovative, non-quantitative approaches may be applicable, e.g., principled bargaining techniques (Dorcey). In almost all cases, however, a certain amount of quantitative data will be required.

One of the benefits that would come from a systematic review of important environment-economy issues in Canada is an identification of the key data at various levels (local, regional, etc.) that should be continuously collected to provide consistent data bases. These data could be used to examine specific issues in specific regions of the country (see Annex 1 regarding U.S. Integrated Regional Modeling projects).

The following chapter describes the approach used during this study to search for existing environment-economy data. Annex 2 includes the results of preliminary searches for data and information concerning a sample set of environment-economy issues that are currently relevant to Canada. While this preliminary effort revealed serious data deficiencies and structural problems in the databases sampled, the application of the suggested approach has proved very helpful in the search process. On the basis of this experience, it is recommended that an approach such as this be adopted in future research efforts.

SEARCHING FOR ENVIRONMENT-ECONOMY INFORMATION

An abundance of literature on environment-economy interactions exists, but the researcher seeking such data must be aware of both the avenues and the obstacles to finding the information. Pitfalls and difficulties in locating environment-economy data should be taken into consideration before beginning the search process. Difficulties occur for the following reasons:

— The concept of environment-economy interactions is very broad and spans a number of professional and scientific disciplines, for example, biological sciences, agriculture, economics, and industrial management. This requires a great deal of "lateral thinking" when searching the literature and databases.

— Much of the information on this subject is found in the "grey literature" — meaning unpublished government and industry studies, conference proceedings, consultants' reports, and other sources not always accessible through conventional library or database literature searches. Researchers should be prepared to use more "unorthodox" means to identify and obtain this type of information, including telephone enquiries and written requests to individuals, government agencies, or organizations working in the relevant area.

A Review of Sources

Published literature is comparatively simple to locate using either manual library searches, or through bibliographic computer literature searches. Each method of searching offers some advantages, and both should be used to obtain the most comprehensive subject bibliographies.

Manual Literature Searches

A manual search refers to the traditional library literature search involving the use of library catalogues, special indexes to periodical literature, subject bibliographies, and regular scanning of key journals in the subject area. Key environmental library collections in the Ottawa area include the Canada Institute for Scientific and Technical Information, Environment Canada's network of libraries, and the Carleton University. Major indexes and abstracting publications covering environmental publications are Environment Abstracts, Environment Index, Government Reports Announcements (U.S. National Technical Information Service), and Pollution Abstracts. However, the searcher should be aware that other indexes, in related fields, may also provide useful information; for example, a search of Forestry Abstracts would be useful for obtaining information on the impact of acid rain on forest resources. Similar subject indexes exist for most scientific disciplines. (Note that an increasing number of printed indexes and abstracting publications correspond to bibliographic computer databases, and can be accessed by either means.)

Bibliographic Computer Database Searches

Bibliographic computer databases have proliferated at a rapid rate over the past decade, largely in an attempt to deal with the tremendous increase in the amount of published scientific literature. A database search can quickly provide a researcher with an extensive subject bibliography. While some general concepts apply to bibliographic databases, there is a great deal of variation among the individual databases. An understanding of three things is required to obtain useful results from on-line (computer) bibliographic database searches:

— an understanding of the subject to be searched, and of how this subject can be broken down into concepts, keywords or phrases, and their synonyms;

— an awareness of both the on-line search "strategy" for carrying out a database search, and what databases can and cannot provide; and

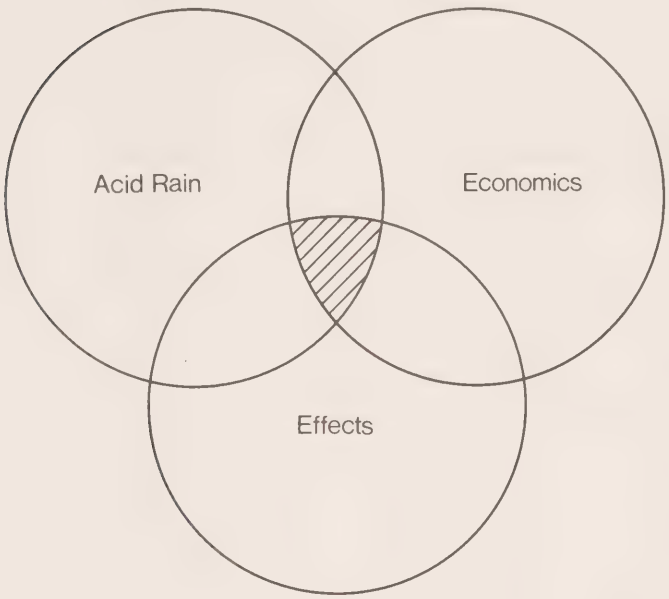
— the unique features of the database(s) chosen for the search, including the subject and time coverage, document-type coverage, and searching techniques and restrictions.

Basically, an on-line search is a search of a computerized index. As with a printed index, the particular topic of interest is accessed through subject headings, or in the case of databases, through "keywords", "descriptors", or "identifiers". (these may be single words or phrases.) One of the main advantages of on-line database searches over printed index searches, is that keywords can be used in a number of combinations using the Boolean operators, "AND", "OR", or "NOT". These allow the search to be defined more precisely than is possible in a printed index, in which only one term at a time can be searched.

Boolean operators can best be visualized diagrammatically. For example, if the search topic is "economic effects of acid rain", the search terms or keywords might be broken down into groups of concepts and their synonyms as follows:

Concept A	*Concept B*	*Concept C*
acid rain	economy(ics)	effect(s)
air pollution	socio-economics	impact(s)
		cost(s)

In the database search, the term "acid rain" will retrieve a set of references containing this term either in the title, or in the descriptor, identifier, or abstract field. (Any of the fields may be excluded from the search. Often it is useful to eliminate the abstract field, as too many general references may appear.) A set is compiled for each search term. The "OR" operator is used to link the synonyms for each subject before the different concepts are linked with "AND". When the terms are combined using the operator "AND", the result will be a subset of these references, i.e. only the references that contain all three terms.



The shaded area in the diagram above represents the references that contain all three search terms and, therefore are most likely to be relevant to the subject. (To keep the diagram simple the synonymous terms are not shown.)

The "NOT" operator can be used to exclude terms, for example, "pollution not water pollution".

Each database to be searched for references must be considered individually. A single search strategy may not be appropriate for all databases, even though the subject remains the same. Different strategies are called for because of the variable structure and coverage of databases. Databases vary in the following ways:

— *Dates of coverage:* Some databases cover literature dating from the 1960's or earlier, while others do not cover material published before 1970. Some databases are updated frequently (some monthly), while others are as much as two years out-of-date.

— *Subject areas:* Most databases have a subject specialization, for example, agriculture or business. However, because scientific subjects are somewhat interrelated and interdisciplinary, it is often necessary to consider a wide range of databases to obtain comprehensive coverage. For instance, a search on the topic "the economic effects of acid rain" might include environmental, business, economic, and general (i.e., newspaper and media) databases. Each database will cover different sources of information on the topic.

— *Document coverage:* In general, database searches are useful for data published in standard sources such as journal articles, published conference proceedings, and government/institutional reports. Databases vary considerably in coverage of other materials, for example, monographs, consultants' reports, special studies, and corporate research. Some databases cover only a specific type of publication. For example, NTIS includes only government sponsored research, and Infoglobe covers only articles published in the Globe & Mail newspaper.

— *Special features:* Databases are published by a variety of commercial/ institutional organizations. Each database uses different indexing terms or thesauri and different formats for their references. Some allow the searcher to limit searches in a number of ways, for example, to items designated as "major" materials; to specific types of materials, or to a particular geographic area. The capabilities of each database must be evaluated and incorporated into the search plan to obtain the most relevant references. Database suppliers publish brief guides to their databases. These guides show the special features of each database, and reference should be made to the guide when planning a search. Publishers also issue detailed instruction manuals for their databases. It is useful to obtain the manuals for frequently searched databases, as they provide information on the methods of indexing and subject terms, as well as techniques for searching, and for sampling searches.

Some databases likely to be useful in searches concerning environment-economy interrelationships and related subjects are listed below. Brief descriptions and notes of special features are included.

Database	*Dates of Coverage*	*Description of Coverage*	*Features*
(Dialog databases)			
Agricola (Files 10, 110)	1970-present	Produced by the U.S. Department of Agriculture. This database is an international index to agriculture-related publications, including agricultural economics.	— some abstracts — language limit — thesaurus and user's aids available
APTIC (File 45)	1966-78	Air pollution references, including economic impacts. Produced by the U.S. Environmental Protection Agency. Useful for non-conventional literature, but only for this limited time span.	— abstracts — language limit — thesaurus available
CAB Abstracts (File 50)	1973-present	This database is produced by the Commonwealth Agricultural Bureaux and offers worldwide coverage of all fields of agricultural science.	— abstracts — category limits — user's aids available
* Canadian Business & Current Affairs (File 262 — soon also available on CAN/OLE)	1980-present	170 Canadian business journals and 10 newspapers are indexed for "business perspectives" on industry, economy, government policy, etc. A current affairs database.	— no abstracts
Dissertation Abstracts Online (File 35)	1861-present	U.S. and some Canadian dissertations and theses. All areas of science, economics, and humanities are included.	— abstracts for post 1980 references
DOE Energy (Files 103, 104)	1974-present	Information on energy-related issues, including the environment, policy and economics of energy. Compiled by the U.S. Department of Energy, it includes journal articles, conference papers, dissertations and translations from international sources.	— limits by major descriptor — abstracts — indexes of special terms, i.e. popular terms — user's guide & thesaurus available
**Economic Literature Index (File 139)	1974-present	260 economics journals and approximately 200 monographs are monitored annually. Includes information on economic growth, planning, urban and regional economics, and natural resources.	

Database	*Dates of Coverage*	*Description of Coverage*	*Features*
**Economic Abstracts International (File 90)	1974-present	International coverage of economic research, including theory and public policy. Approximately 50% of coverage is devoted to European sources.	— descriptor codes — no abstracts
Energyline (File 69)	1971-present	Covers all aspects of energy, including environmental and economic issues. Conferences, journals, government reports, and monographs are included.	— abstracts — major/minor limits — user's manual & thesaurus available
**Enviroline (File 40)	1971-present	International environmental issues are covered. More than 5,000 primary and secondary sources including government reports, journals, conferences, newspapers, films, and monographs are covered.	— abstracts from 1975 to date — major/minor limits — review classification — user's manual available
**Environmental Bibliography (file 68)	1973-present	General human ecological environmental research. Only journals (over 300) are indexed.	— no abstracts — vocabulary aid available
**Life Sciences Collection (File 76)	1978-present	A general life sciences database that includes environmental/ecological studies from a broad range of sources.	— language limit — abstracts — thesaurus & user's guide available
**Magazine Index (File 47)	1959-1970, 1973-present	Interdisciplinary database covering approximately 450 popular magazines for general reference use. Covers current affairs, environment, economics, business issues, etc. (Latest months reference are included in Newsearch database, File 211).	— no abstracts — full text of some articles available in File Magazine AESP — thesaurus available
Management Contents (File 75)	1974-present	Business and management related subjects covering policy and planning and decision-making information for industry and government.	— abstracts — descriptor codes

Database	*Dates of Coverage*	*Description of Coverage*	*Features*
Medline (Files 152, 153, 154)	1966-present	Covers literature on all areas of biomedicine. Over 3,000 journals are monitored regularly. Some coverage of monographs is given.	— abstracts — can be limited to human/non-human subjects — major/minor limits — thesaurus
Occupational Safety and Health (File 161)	1972-present	Over 400 journals are regularly indexed, and 70,000 monographs are included in this database dealing with the work environment.	— abstracts — language limit
**Pollution Abstracts (File 41)	1970-present	Covers all areas of environmental quality.	— abstracts — descriptors and added terms — language limit — user's guide & thesaurus
SciSearch (Files 34, 87, 94, 186)	1974-present	A multi-disciplinary index to science and technical literature, including environmental sciences.	— no abstracts — language limit — article/non-article limit
Social SciSearch (File 7)	1972-present	A multi-disciplinary database that indexes over 1,500 social science journals and additional monographs and journal sources internationally. Economics literature is included.	— no abstracts — language limit — article/non-article limit
(Can/Ole Databases) **NTIS (National Technical Information Service) (Also available on Dialog)	1964-present	A multi-disciplinary index to U.S. government sponsored research from over 300 agencies. Environmental and socio-economic literature is included, and some non-U.S. government reports available for sale from NTIS are also included.	— abstracts from 1982 — environmental microthesaurus available

Database	*Dates of Coverage*	*Description of Coverage*	*Features*
* ELIAS (Environment Libraries Automated System)	1976-present	This database indexes the library holdings of 15 Environment Canada libraries. Monographs, serials, conference proceedings, and reports are included.	— no abstracts
* OON (Canada Institute for Science & Technical Information Catalogue)	1978-present	This is the catalogue of the national science library in Ottawa. Monographs, conference proceedings and technical reports in all fields of science are included.	— no abstracts
* Electric Power Database (QL Systems Databases)	1972-present	Covers research in the U.S. and Canadian electric industry, including economic/environmental studies	— abstracts
* Canadian Environment **Database (CENV)	1970-present	Contains over 65,000 references to scientific, technical and general articles on all areas of the Canadian environment. Journals, proceedings, and government reports are covered.	— abstracts — geographic limits
(Globe & Mail Database) * Infoglobe	1977-present	This database indexes articles in the Globe & Mail newspaper. General media coverage of the Canadian environment/economy is included.	— full text of articles available on-line

* Indicates Canadian content is emphasized in the database.

** Designates primary databases for this topic. Others are also likely to have useful information but should be searched after, or in conjunction with, the main subject area databases

Preliminary Searches of Selected Databases

To make a preliminary assessment of the type and form of information that is readily available to Canadian researchers, searches of several selected databases were completed. The results from these searches were mixed, because wider ranging, more specific searches of many data sources (both published and unpublished) are required to complete an analysis of a particular issue or question. There are some observations, however, that can be made on the basis of the "sample" searches.

The application of the analytical approach proposed in the preceeding chapter (i.e., specifying the systems affected, time frame, spatial context or aggregate level, activities, and technologies involved) was of considerable assistance in collecting relevant data. The usefulness became apparent when the search strategy was being designed. The point to note, is that one must know what one is looking for before data or information is sought. Searching for information without a clear purpose or analytical rationale will not contribute either to understanding a subject, or to drawing informed conclusions.

An important finding of this review of environmental-economics literature and techniques concerns the unique nature of environment-economy relationships. This uniqueness implies that the application of findings of similar or related research that is based on one set of circumstances, at one location, at one time, and which perhaps involves different technology, will not necessarily be appropriate to solving a related problem elsewhere. There are, of course, many benefits to be gained by reviewing similar research efforts completed elsewhere. The experiences, findings and conclusions of this research can be of great assistance to researchers who want to frame properly the research questions that they wish to examine. In most cases, however, such conclusions or data should not be used to draw direct conclusions concerning different environmental-economic problem sets.

Searches for Publications Concerning the Subject of Environment-Economy Interrelationships, Linkages, Effects, etc.

These searches were undertaken to get a "feel" for the quantity of publications and information available, and an indication of the type of information included. The searches were completed on the following databases:

— *Enviroline*

— *Magazine Index*

— *Economic Literature Index*

— *N.T.I.S. U.S Department of Commerce*

— *Environment Canada: Departmental Library*

Two particular observations were made, based on the output of these searches: (1) the subject is so diverse that specific topics within the field include a mix of general and theoretical treatments; and (2) there was also an indication, from this sample, that economics-oriented databases may provide more specifically applicable input to the problem in terms of quantitative data. The organization and character of the databases searched were quite variable and, therefore, no broad generalization can be made about their content.

Sample Searches Using Sample Environment-Economy Issues or Problems

A selection of databases including Environment Canada Departmental Library, Enviroline, and Pollution Extracts were used to test the use of the systematic approach discussed in Chapter 3. A set of problem descriptions were defined and searches conducted for the first example (economic effects of soil erosion) according to a comprehensive set of headings. Five other examples were searched less exhaustively, because it was found that the specification of comprehensive categories was too broad for the purpose of "targeting" specific information. It should be noted that this problem is one that must be resolved database by database, due to their non-standard design.

A report on the results of the searches is presented in Annex 2. Only two sample print-outs have been included in the final version of this report. Photocopies of the others are available on request. The samples included indicate the approach used and the kind of results that can be expected of database searches in this subject area.

CONCLUSIONS AND FUTURE RESEARCH NEEDS

Conclusions

This brief research project has established several points that provide a starting point for future work in the area. They include:

1. The interdependencies found in society, involving economic activities and environmental systems and sub-systems, are complex and pervasive.

2. The traditional neoclassical economic theoretical framework, based upon individual preferences and utility, market dynamics and income flows, etc., is not sufficient to understand the interactions and interdependencies between particular economic systems and environmental systems.

3. Various methodologies have been developed and used in recent years to create analytical models to explain the linkages and interdependencies between environmental quality and economic performance. Each of these has limitations, but there has been a general trend toward greater integration and linkage of individual systems or sub-systems to form more realistic representations of reality.

4. For analysis of interdependencies to yield meaningful, applicable results in the form of policies and other actions, the analysis must be completed at a level of disaggregation that permits separation and identification of the roles played by various major factors. Therefore, analysis of a river basin or other regional level unit is likely to yield more insight than larger aggregations of data. Analysis at the national level for a country the size of Canada will not provide the information required to separate the distinct and different effects and consequences that occur across 8,000 kilometers of geography.

5. Analysis of questions of environment-economy interdependency and policy impact requires a systematic analytical framework that includes:

   — problem definition and description;

   — data collection and organization;

   — analytical models and related theory;

   — testing and comparing policy alternatives; and

   — evaluation criteria.

   This approach will assist policy makers, researchers and lay persons in deriving useful insights, and will contribute to more informed judgements regarding particular policy choices or action plans.

6. The published databases provide a vast array of information, but the information and data require sorting and evaluation to determine their usefulness in analysing specific Canadian interdependency questions. There is a need to complete a region by region review of data that are basic to environmental-economic system analysis in Canada.

7. Progress has been made in the areas of multi-objective analysis, conflict analysis and negotiated resolution of issues between various interest groups in society, i.e., environmental-economic conflicts and competition. In view of the likelihood of continued data gaps, and the unquantifiable nature of some of the factors involved, these techniques and theories may play an important role in the resolution of particular resource-user conflicts in the future.

A summary list of research that should be considered follows. It is clear that the review just completed does not adequately describe the status of all similar, relevant research across Canada. While it is recommended that detailed data collection and analysis be undertaken on a continuous regional basis, it is also recommended that co-ordination between regional research efforts be "built in" from the outset. Ensuring that such co-ordination takes place, and that integration of regional analysis occurs is a vital task.

Summary of Future Research Needs

A review of current Canadian research in the area of regional and multi-regional environment-economy models should be completed. This review should:

a) identify

- — modelling efforts currently underway;
- — boundaries and duration of these analyses;
- — the types of data and databases available or being constructed;
- — resource groups involved, e.g., universities, institutes, departments of government, others;
- — the level of commitment and interest of public and private sectors in various regions to establish improved bases for evaluating environment-economy relationships; and
- — the policy setting and policy issues or obstacles to establishing the above commitments in each region.

b) complete

- — an annotated bibliography of regional data and information relevant to interdependency modelling and analysis; and

— an annotated bibliography of techniques and theory useful in the analysis of linkages between economic and environmental systems.

c) encourage — launching of a co-ordinated long-term multi-regional research effort that would include all relevant levels of government, institutions and the private sector;

— the development of comprehensive environmental-economic system data bases for each region of the country;

— the use of integrated environment-economy policy analysis by local, provincial, and national policy makers; and

— public awareness of the important relationships between environmental quality and economic prosperity.

REVIEW OF ANALYTICAL APPROACHES

In the course of developing an analytical approach for assessing environment-economy interdependencies, a number of techniques were reviewed. A brief description of each has been included in this Annex.

Input-Output Analysis[1]

Input-output analysis consists of tables that describe, for a number of sectors in the economic system (e.g., agriculture, manufacturing industries, public utilities, service sectors), the inputs to the production process during a certain period of time. These inputs are primary inputs, such as labour and capital stock; secondary inputs, which are goods and services produced by the above sectors; and imports of goods and services from outside the economic system. The tables also describe the outputs of goods and services produced by using the above-mentioned inputs. The outputs are exports and final deliveries to households, firms (investment goods), and governments. These flows are usually expressed in monetary ($) units.

In an extended input-output framework, several parts are added to the basic input-output (I-O) tables to describe the emissions of different types of environmental pollution caused by activities of the various sectors in the economic system. Also described are the activities of sectors existing entirely for abatement of pollution, while other elements are added to describe pollution and pollution abatement.

The approach, however, is not without problems. Leontief and Ford (1972), in applying the above-mentioned framework to the economic system of the United States, encountered considerable difficulty in obtaining the data for emissions of various types of pollutants caused by various sectors of the economy. Data for the abatement sectors were not available at all.

Although the extension of an input-output framework to environmental phenomena appears to be straightforward, it leaves several problems unsolved. Some problems result from the use of input-output models, and others stem from the manner in which environmental repercussions are modelled. Some of the limitations and shortcomings of I-O analysis are listed below:

— Utilizing the input-output model as the production function in an economic model means that implicit assumptions are being made that the production processes of each firm in each industry are identical.

— Substitution between inputs as a result of pollution abatement may be neglected.

— The effects of international competition between national industries is not taken into account.

— Little attention is given to other means of reducing emission of pollutants. For instance, when the importance of environmental conservation is acknowledged, new versions of capital goods may have quite a different technical profile than the existing capital stock. These other means may include more efficient use of (other) raw materials, and the recycling of waste products.

— Pollution streams may be treated conceptually as distinct sectors. In reality, pollution is often treated by end-of-the-line equipment which is installed by the polluting firm itself.

— The differences in response rates and timing between the economic processes and the ecological processes, in which the economy is embedded, are not adequately reflected.

These limitations on the use of input-output analysis have led to important adaptations. Methods have been developed to adapt input-output co-efficients to changing technological circumstances (Linear Programming methods, and Quadratic/Least Squares methods). However, none of these methods takes technological change into account internally. Instead, they describe technological change only after it has occurred.

Although input-output analysis has its theoretical flaws and disadvantages, it is widely used because it is, at least, operational. Over the last decade, input-output models have become a part of many economic-environmental studies. Polenske (1976), Muller (1980), and others, gave specific attention to energy problems in input-output analysis. Nijkamp and Paelinck (1976), Coupe (1977), and Muller (1980), constructed economic-environmental models on the basis of an input-output framework. Den Hartog and Houweling (1974), used an economic-environmental input-output model to study price effects of pollution abatement. This model resulted in more general studies of the macro-economic consequences of environmental policy.

Cumberland and Stram (1974) provide a good example of how the original method of extending input-output models (proposed by Leontief and Ford 1972) has developed. Cumberland and Stram avoid the problems that arise regarding strict, isolated, input-output modelling by linking the model (with distinct energy sectors) to a larger economic-environmental framework. This analytical approach is depicted in Figure 6.

[1] Adapted from Hafkamp (1984).

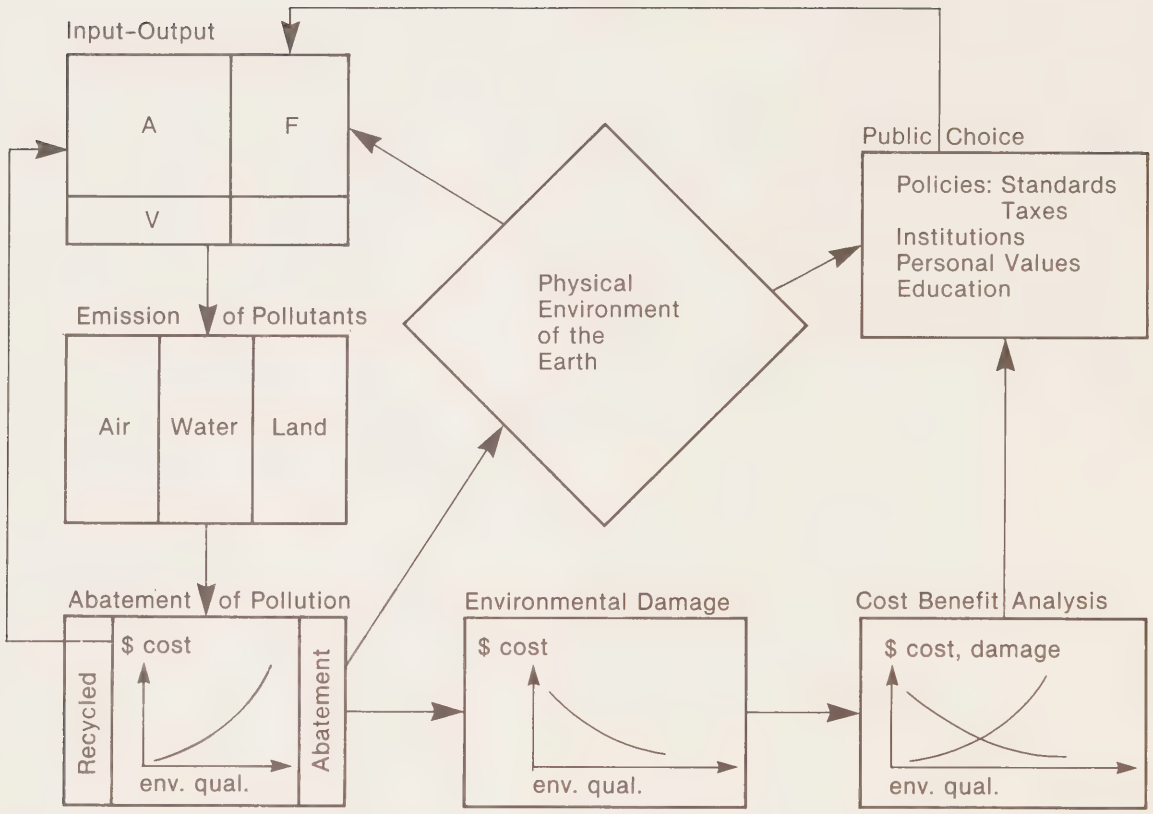


FIGURE 6
Input-Output Analysis as an Integrated Part of Economic-Environmental Modelling

Materials Balance and Ecological Systems Models

While input-output models describe flows of goods and services in economic terms, materials balance models rest upon the same basic idea but describe flows and stocks of energy and materials from an ecological point-of-view. A simplified depiction of this model is shown in Figure 7.

Materials balance models may be constructed on any spatial scale (an office building, a region, a country, etc.). Therefore, this type of model is very useful in multi-regional economic-environmental modelling.

The materials balance model approach has, however, several limitations:

— For some toxic chemical compounds, the main problem is not the mere existence of waste. The conditions under which waste is released into the environment, plus the dispersion process of residuals, may be far more important. Also, insignificant amounts of toxic wastes may have very significant impacts.

— The relevance of the analysis of environmental effects and the influence on ecological processes is limited. The model basically describes human activities that involve using and disposing of materials and energy.

— The description of economic processes in materials balance terminology, (usually quantified in volume or weights) may be very awkward where, for instance, it involves determining interest rates in ($) or describing specific processes.

A recent application of the materials balance approach is found in the statistical representation of energy flows in the Netherlands. The Dutch Central Bureau of Statistics (CBS) used the concept of energy balance for this purpose (Van Strien 1980).

Input-output analysis and materials balance models are important tools for economic-environmental analysis. Both types of models are supplementary (operationality, comprehensiveness) and, sometimes, complementary (monetary flows, materials flows). Their respective disadvantages do not outweigh one another. Both approaches provide partial models of the economic-environmental reality.

Integrated Environmental Impact Analysis[2]

Integrated environmental impact analyses require specification, in some detail, of the interdependencies and linkages between various system components. Among the prerequisites for a satisfactory integrated environmental-economic analysis are the following:

— The analysis should have a degree of disaggregation and variation that allows the differences between sub-systems to be observable.

— The interactions within and between sub-systems should describe links in a satisfactory manner.

— An actual operational application of the analytical approach should be possible using either quantitative or qualitative measures.

— The analysis should provide sufficient and relevant information for a decision-maker who has to judge various policy alternatives.

2 Adapted from Nijkamp (1980), pp. 11-12.

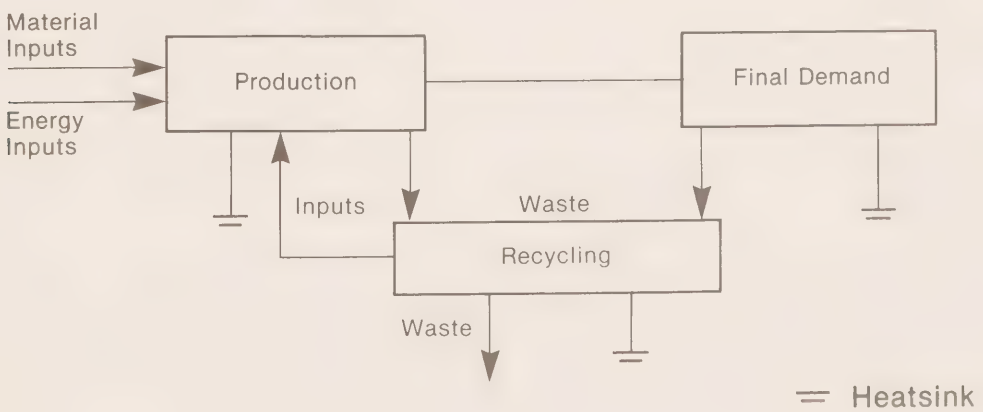


FIGURE 7
Structure of a Materials Balance Model

In practice, two problems often hamper a straightforward integration of economic and environmental variables:

— The spatial scale of many ecological variables is sometimes very small, e.g., square metres, while the scale of many economic variables is large, e.g., a country. This difference in scale means that micro-oriented research data of ecology/biology cannot always be directly integrated with traditional economic analysis.

— The time frame of different disciplines varies. Ecological analyses extend over long periods, perhaps decades, while economic analyses tend to emphasize short-term (months) to medium-term (years) effects. This difference in time dimension is a problem when attempting to integrate environmental and economic components.

Integrated Environmental Modelling[3]

The concept of integrated environmental models is a fairly new approach in environmental economics. These models attempt to incorporate the great diversity of real-world phenomena, including the interdependencies between these phenomena. The following is only a partial listing of the many elements that can play a role in integrated environmental models.

— *Environmental Impacts:* flows of pollutants in air and water, solid waste, and toxic waste;

— *Ecological Systems:* terrestrial and marine ecosystems, food chains, nutrient cycles, etc.;

— *Resources Management:* the extraction, transportation and treatment of coal, oil, gas, and ore; the determination and distribution of fishing quotas; and forestry;

— *Economic Systems:* national, regional, and local economic systems; firms, plants, and urban economic systems;

— *Social and Political Systems:* employment patterns, and public decision-making systems;

— *Transportation Systems:* these systems as elements of economic systems and spatial systems;

— *Demographic Developments:* population dynamics, and educational profiles.

Integrated environmental models can be constructed for such widely varying purposes as:

— *global resources management:* such models are currently being developed by Isard et al 1981 (see also Forrester 1971; Meadows and Meadows 1972; and others);

— *national energy planning:* (see House 1980; Driehuis, Van den Noord and Van Ierland 1983; and others);

— *land use planning:* (see Arntzen, Braat 1982); and

— *regional planning, and transportation network planning.*

The purposes for which integrated environmental models are constructed vary widely, as do the ecological, economic, and other processes reflected in these models. It is not surprising, therefore, that a single, generally accepted framework for such models does not exist. Various attempts in this respect have been made, one of which is discussed below.

An Integrated Structure for Economic-Environmental Interactions[4]

This system is subdivided into three sub-systems: a socio-economic sub-system (E), an environmental sub-system (M), and a geographic-demographic sub-system (G). In the framework of environmental analysis, a central role is played by the environmental sub-system.

The environmental sub-system consists of two parts: a first part which represents the general quality indicators of an ecosystem, such as ecological stability, etc.; and a second part which represents the direct environmental consequences of human activities, such as the impact on the variety of an ecosystem.

A simplified representation of an integrated economic-environmental system is shown in Figure 8. It is clear that one may also distinguish intra-relationships (within each sub-system) and inter-relationships (between the sub-systems). It should be noted that the element of space may play a double role in Figure 8 as the medium through which the sub-systems are linked together, and as the geographical location of all activities performed in the system, e.g., land use.

The choice of the variables of the E, G and M systems is a matter which is determined by the aim of the analysis, for example, a structural description, an integrated impact analysis, a detailed prediction, or an estimation of consequences of policy scenarios. In general, however, one should try to keep the number of variables and the number of relationships as low as possible.

The elements of each sub-system can also be incorporated in a multi-dimensional profile or vector. In general, the E, G and M sub-systems will contain the following elements (functions, quality indicators, state indicators, etc.), respectively:

E Sub-system

— production (divided among sectors);

— investments (including abatement investments);

[3] Hafkamp (1984), pp. 25-30.
[4] Adapted from Nijkamp (1980), pp. 12-13.

— supply and demand of labour per category;

— value added and expenditure pattern (including income distribution etc.)

G Sub-system

— demographic structure;

— migration and commuting;

— population density and urbanization rate;

— reaction;

— urban facilities;

— congestion;

— etc.

M Sub-system

The M sub-system can be divided into C sub-component and I sub-component:

C sub-component

— natural areas;

— types and quality of flora and fauna;

— ecological quality indicators (diversity, stability, etc.); and

— descriptive indicators for various landscape structures.

I sub-component

— air, water, and soil pollution;

— noise annoyance;

— extraction of raw materials; and

— land use.

The three profiles noted above make up the basic structure of an integrated economic-environmental analysis. Clearly, one might also add a social sub-system, but doing so would make the system more complex. Furthermore, the possibility of operationalizing such a sub-system profile is limited.

In addition to the first step in this integrated analysis, i.e., the identification of all system components, one has to specify the various relationships between the elements, both the intra-relationships and the inter-relationships. A first step may then be to construct the relations matrix between E, G, and M. This matrix will: 1) indicate the existence of relationships; 2) act as a directional matrix to indicate the directions of the influence (in a positive or negative sense); 3) act as a qualitative structural matrix to indicate the order of magnitude of the various relationships, e.g., by means of ordinal numbers; and 4) serve as a quantitative structural matrix to indicate the impacts of all variables of the system.

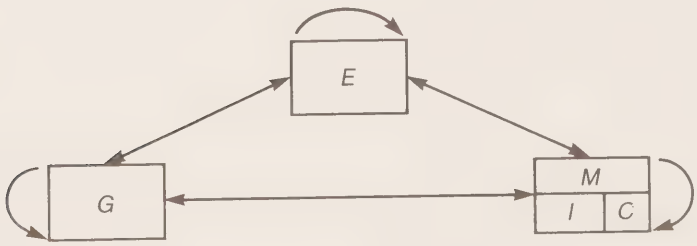


FIGURE 8
Scheme of a Simple Integrated Economic-Environmental System

1 Adapted from Nijkamp (1980) p. 12-13.

Usually, one starts with the first step and then tries to reach the final step during a series of experiments. Quantitative (cardinal) information is not always necessary in order to draw reliable conclusions concerning certain analytical or policy aspects. The various linkages of an integrated economic-environmental model can also be reflected by means of an interaction scheme for the intra-relationships and inter-relationships within the system (Figure 9). The arrows represent the main directions between sub-systems and sub-components.

Figure 9 demonstrates quite clearly that one of the crucial problems in an integrated analysis is the precise calculation of the impacts of human activities, from the E and the G profiles upon the elements of the M profile (both the I and the C sub-profiles). This problem of environmental impact evaluation has been the subject of much research.

Cost-Benefit Analysis[5]

Environmental evaluation aims at assessing the value (social and economic) of changes in the quantity and quality of environmental commodities, so as to provide a tool for calculating the trade-off between alternatives with different environmental and economic impacts. It is evident that in the framework of a neoclassical analysis, the evaluation of environmental commodities has to be based on market prices. When market prices do not exist for environmental commodities, artificial prices, e.g., shadow prices, have to be calculated in order to ensure, for neoclassical analysis, an operational result. Cost-benefit analysis can be regarded as the neoclassical tool par excellence for evaluating environmental commodities.

Cost-benefit analysis goes essentially one step further than an environmental impact analysis, because it assigns a value (a price) to all impact assessments. Some of the shortcomings of cost-benefit analysis are listed below.

— Cost-benefit analysis is only an efficiency criterion, and usually neglects equity criteria.

— It is based on a blend of various costs, for example, real costs, artificial costs, and shadow costs.

— It is partially based on shadow prices, which are ambiguous because they depend on the social welfare criterion at hand.

— In a cost-benefit analysis, it is difficult to incorporate uncertainties, risks and time effects.

— Intangibles can hardly be incorporated, in a meaningful way, in a traditional cost-benefit analysis.

It must be added that several of the above-mentioned problems hold true for any evaluation, but the latter reason (the difficulty of incorporating intangibles) makes cost-benefit analysis particularly inappropriate as an operational tool for environmental commodities. Even adjusted methods, such as cost-effectiveness analysis, are not able to overcome this particular difficulty.

In the field of ecology, several alternative evaluation methods have been developed. Examples are the functional evaluation method, the ecological quality method, and the energetic evaluation method (see Nijkamp 1977).

The functional evaluation method attempts to gauge all ecological and economic functions of environmental commodities in quantitative terms, and then to aggregate all information to a functional environmental indicator. This aggregation, however, normally includes many arbitrary choices.

The ecological quality method aims at characterizing environmental goods by means of quantitative quality indicators (for example, quantity of natural area, and diversity). These quality indicators can be used as an appropriate input for a multi-criteria analysis.

The energetic evaluation method attempts to assess the monetary value of environmental goods on the basis of the energy transfer and production in an ecosystem (via the average national energy price). This method is too arbitrary to be used as a reliable technique.

On the basis of this brief survey of environmental evaluation methods, one may draw the conclusion that several methods developed and employed so far cannot be regarded as satisfactory evaluation techniques for operational environmental policy analysis. Intangible and immeasurable effects are difficult to incorporate in all these methods, and the conclusion is justified that any attempt to transform heterogeneous, unpriced impacts into a single dimension, e.g., quantified value, will fail.

This conclusion has led researchers to look for more diversified multi-dimensional approaches to environmental-economic analysis and impact evaluation.

Multi-Regional Economic-Environmental Models[6]

In economic-environmental modelling, the tendency towards the construction of multi-regional and national-regional models is fairly recent. A worldwide survey of multi-regional economic models was held by the International Institute for Applied Systems Analysis, Laxenburg, Austria, and the Department of Regional Economics, Free University, Amsterdam, in 1981 (see Issaev, Nijkamp, Rietveld and Snickars 1982). The survey, involving approximately 200 multi-regional economic models, showed that 50 models were operational at that time. Only three of these 50 models were economic- environmental models, including the analysis of the energy problem.

5 Adapted from Nijkamp (1980), pp. 17-18.
6 Adapted from Hafkamp (1984), pp. 30-36.

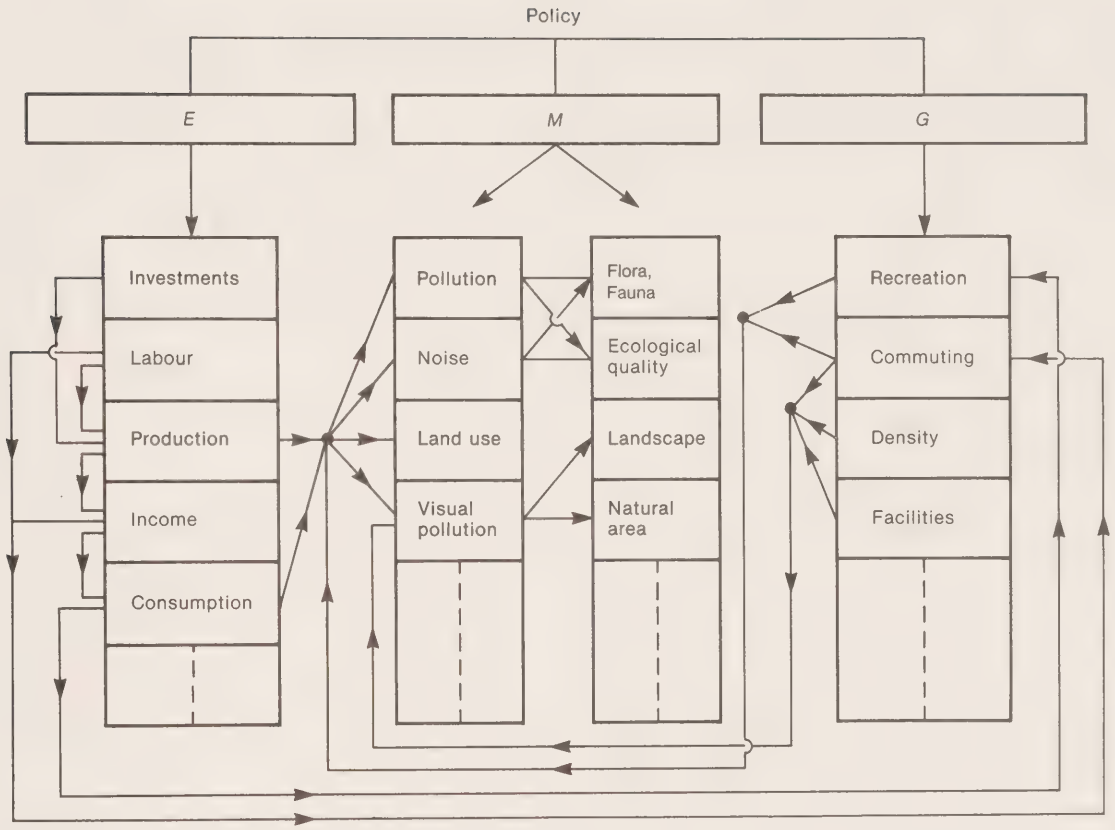


FIGURE 9
Interaction Scheme for an Integrated Economic-Environmental Model

Multi-Regional Model of the Economy, Environment and Energy Demand (MREED). The purpose of MREED is to determine the economic-environmental-energy consequences of alternative national and regional policies for the United States (see Lakshmanan 1979). MREED distinguishes 50 regions within the spatial system, while production of goods and services in those regions is modelled in 53 sectors. The model, shown in Figure 10, has approximately 880 endogenous variables per region.

An outline of the MREED model is contained in Figure 11. MREED is used to estimate regional and, in conjunction with other models, national effects of a wide range of government policies. The model also analyses industrial location within a multi-regional system.

Inter-Regional Policy Model for Energy-Economic-Environmental Interactions (MEEEI). The purpose of the MEEEI model is to study interactions between energy, environment, and the economy in general (see Lesuis, Muller and Nijkamp, 1983). It is a bi-regional model of The Netherlands, modelling the production of goods and services in 11 sectors. The model has approximately 100 variables, which can be comprised as in Figure 12.

MEEEI uses an extended I-O model as its production function. Fixed technical coefficients have been assumed for production factors, labour and energy. The model deals with changes of prices via a particular technique ("translog price possibility frontiers").

Both MREED and MEEEI are currently operational models. The time necessary for their development was considerable, ranging from two to more than five years. A number of models of this type are in the planning or construction stages.

Integrated Multi-Region Model of the U.S.A. (IMR-USA). A promising approach to multi-regional economic-environmental modelling is under development by Isard et al. In 1981, Isard began work on a multi-regional model of the United States by assembling a number of existing spatial models, each of which focused on specific aspects of the multi-regional system, with many overlaps between the various assembled models. Most of the models constituting the Integrated Multi-Region model of the U.S.A. had been developed in previous years by scientists from various universities. Its structure and design were first discussed by Isard, Boyce, Lakshmanan, Klein and Caldwell 1981. Constituting models are:

— *NATLEC:* a national econometric model, used to describe changes at the national level in a number of economic variables, such as prices, final demand, etc.

— *MULTIPOL:* a model using conflict management procedures to describe policy decisions which are basic inputs in other models — government expenditures and energy developments.

— *CICIOP:* this model, developed by Isard, uses location theory (comparative cost) and industrial complex analysis in order to assess optimal production patterns.

— *FACTIN:* a model, developed by Lakshmanan, which determines factor demand (capital, labour, energy, and materials) and regional investments by sector.

— *REGLEC:* developed by Klein, this model is used for projecting employment variables (labour supply and demand, unemployment) and wage rates.

— *DEMO:* constructed by Caldwell, this is a microsimulation model of the household sector, describing expenditure behaviour.

— *TRANS:* an inter-regional transportation model constructed by Boyce.

The inter-relations envisaged between the sub-models of this integrated multi-region model are visualized in Figure 13.

Multi-layer Projection (MLP): A New Method for Economic-Environmental Modelling[7]

In searching for an adequate type of model for integrated, spatial economic-environmental modelling, a number of alternatives have been reviewed:

Traditional economic models, that have been extended by adding energy and environmental variables. The specific disadvantage of this type of model is that it is basically directed towards economic explanation, while spatial and time dimensions may hamper modelling of environmental changes and ecological phenomena.

Materials balance models, are especially suitable for modelling physical flows of materials, energy, products, wastes, etc., but are less adequate for describing choice processes and economic interactions between people, firms, organizations, governments, etc.

Integrated input-output models, which are economic input-output models extended with environmental variables. They describe in detail the origin and destination of flows of goods and services, in addition to describing energy flows and flows of wastes. These models have the same disadvantages as materials balance models.

7 Adapted from Hafkamp (1984), pp. 67-77.

Variable type	National	Regional
Economic	Taxes, Depreciation, Interest rates, Investments	Sectoral Output, Capital Stock, Fuel Prices
Employment	Employment	Labor Demand
Environment		Energy Demand, Number of Heating Days

FIGURE 10
Variables in MREED

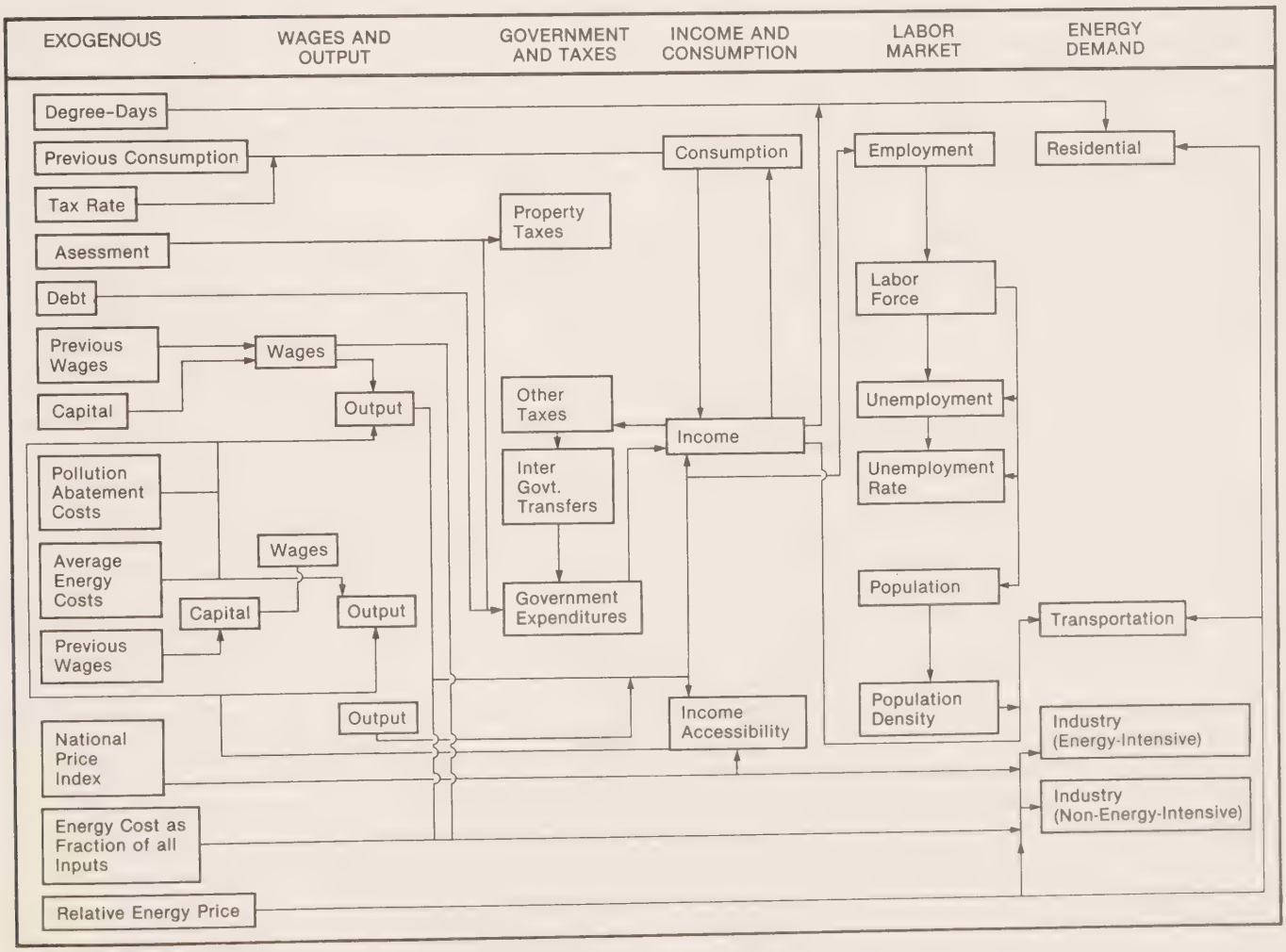


FIGURE 11
Structure of a Multi-regional Model of the Economy, Environment and Energy Demand

Variable type	National	Regional
Economic		Exports, Production
Employment		Employment
Environment		Pollution, Energy Demand

FIGURE 12
Variables of MEEEI

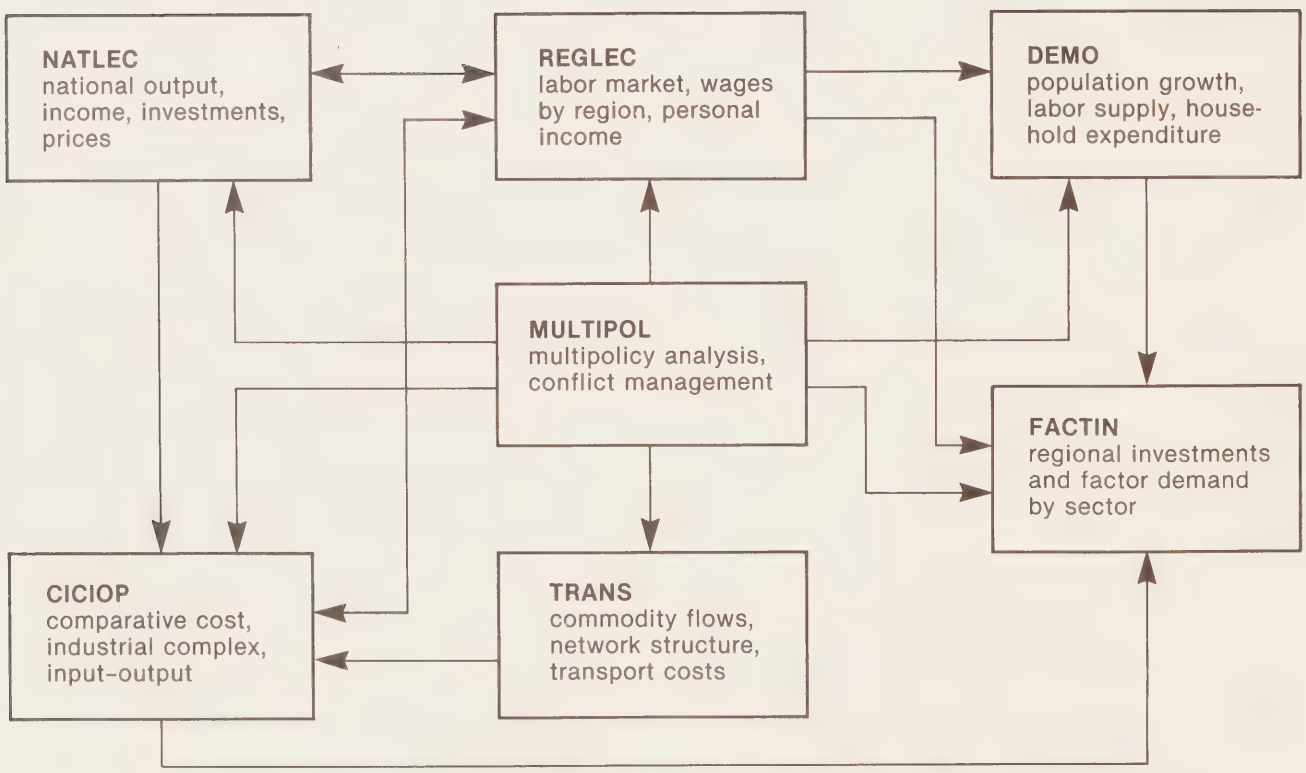


FIGURE 13
Integrated Multi-region Model of the USA

Economic and materials balance models both give a reduced image of processes that take place in reality, and both provide an image of relationships between people, firms, etc. Figure 14 illustrates an economic model that primarily indicates which monetary flows exist in an economic system as counterparts of flows of physical goods and services. Figure 15 shows a simple environmental model that displays the physical flows of goods and energy. Some categories, such as consumption and production, are included in both types of models; other categories, such as income transfer payments to households by the government, typically belong to one type of model.

Both types of models reflect interactions between identical actors (firms, consumers, etc.) in the same spatial system, while also involving different spatial relationships, different dynamics, and different dimensions. The projection of sets of these sub-models on a number of parallel layers (according to spatial and time assumptions) creates what Hafkamp (1984) has labelled a "multi-layer projection". If reality is to be conceived as both an economic system and an environmental system, models of both types should be linked — while remaining apart — thus becoming sub-models of a multi-layer model. This is schematically illustrated in Figure 16.

The principle of multi-layer projection, is, according to Hafkamp, suitable for integrated modelling at the intermediate and micro-levels. A good example can be found in the modelling of power generating systems. Simplified representations of power systems models serve to illustrate. If modelling is completed in solely economic terms, as reflected by Figure 17, the analysis emphasizes economic factors such as investment, interest, cost of fuel, operating costs, production volume, etc.

An economic model as depicted in Figure 17 may be constructed for any mode of power generation, whether it be fossil or nuclear fuels, solar radiation, wind force, or other inputs that are used for the production of electricity. A specific problem with this type of modelling is the conversion of energy values (measured in joules, for example) into monetary values. Fuel prices depend heavily on the momentary position of suppliers and buyers on the fuel markets. Fuel prices, therefore, may not be a suitable measurement for assessing the effectiveness of power generating systems.

An alternative method for modelling power generation is to construct a model entirely in energy terms — a model that estimates the energy effectiveness of a power generating system. An argument in favour of this approach is that, in the long run, energy prices reflect their energy content. A simple example of such a model is given in Figure 18.

A major problem in constructing energy balance models, as depicted in Figure 18, is that a great many financial cost categories, such as investments in construction, interest payments, etc., are transformed into energy values.

Since both modelling approaches have firm disadvantages, it may be useful to apply multi-layer projection to this modelling problem. Projecting one and the same reality on two parallel layers (economic and energy layers), causes both the economic and energy balance models to become sub-models of an integrated economic-energy model. This is schematically represented in Figure 19.

In the two examples of multi-layer projection just discussed, two layers were used for modelling reality according to both its economic and physical dimensions (matter and energy). Modelling should not necessarily be limited to these two layers. In a spatial system, for example, a third layer may be introduced that is specifically designated to model employment, demographic, and socio-political aspects of reality.

It is also possible to distinguish inter-layer relations that cannot be described in any single layer. For instance, the influence of environmental pollution (depicted in the environmental layer) on the consumption process (depicted in the economic layer), may be reflected by an inter-layer relationship.

A Triple Layer Model: Simple Version

Spatial, integrated economic-environmental models are very complex. The simple model illustration provides a rough sketch of the scope and structure of the analysis and of the application of the principle of multi-layer projection.

The model allows for the simultaneous analysis of the effects of economic, employment, and environmental policies on both the economic effects of alternative policies and actions by government, political parties, interest groups, industry, etc.

Although there are many possible foci for analysis, three are represented:

— economic growth

— employment

— environmental quality

Each of these interest is associated with one layer of the multi-layer projection, as shown in Figure 20.

The spatial element in the analysis is of great concern, as there is an analytical difficulty at this point. Economic impacts are easier to measure at the national level. Disaggregation to regions is possible, but often difficult due to data problems. These problems do not apply to environmental phenomena, such as emission and dispersion of pollutants. Environmental analysis should be undertaken at a local level in order to obtain meaningful results on, for example, air or groundwater quality. For the analysis undertaken in The Netherlands, a regional scale was chosen as a compromise between these two divergent demands concerning spatial scale.

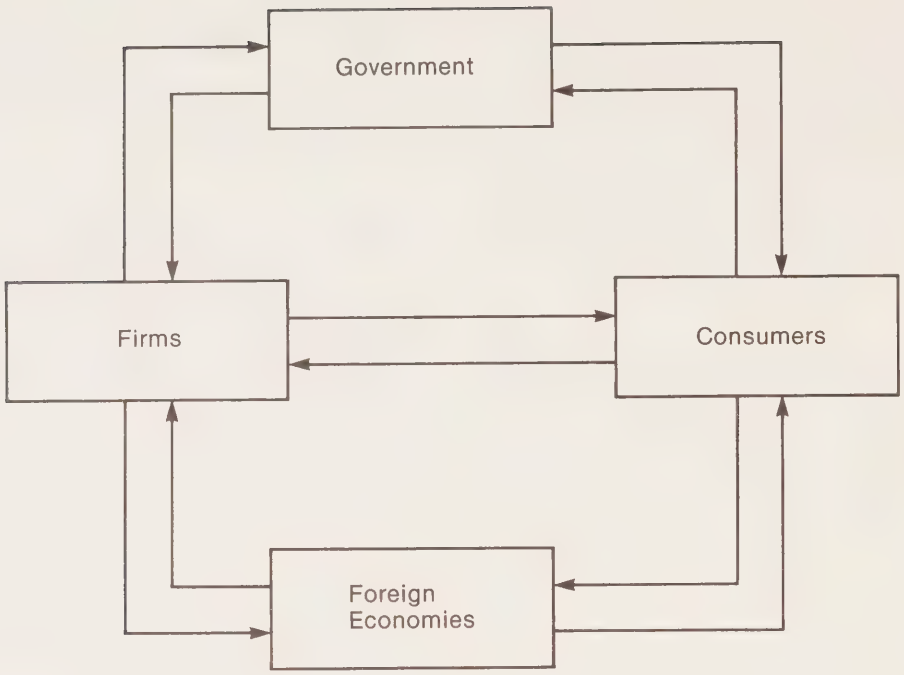


FIGURE 14
Basic Representation of an Economic System

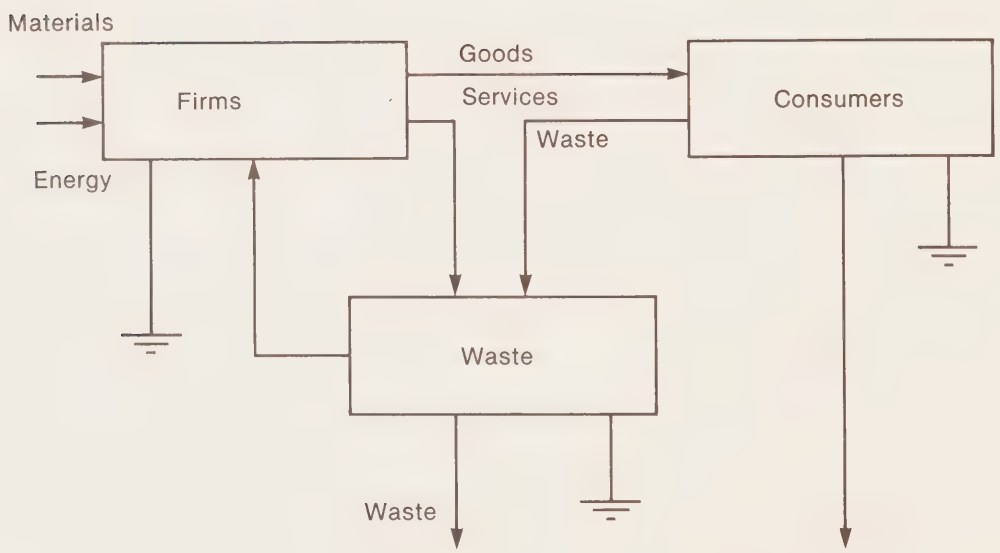


FIGURE 15
Basic Representation of an Environmental System

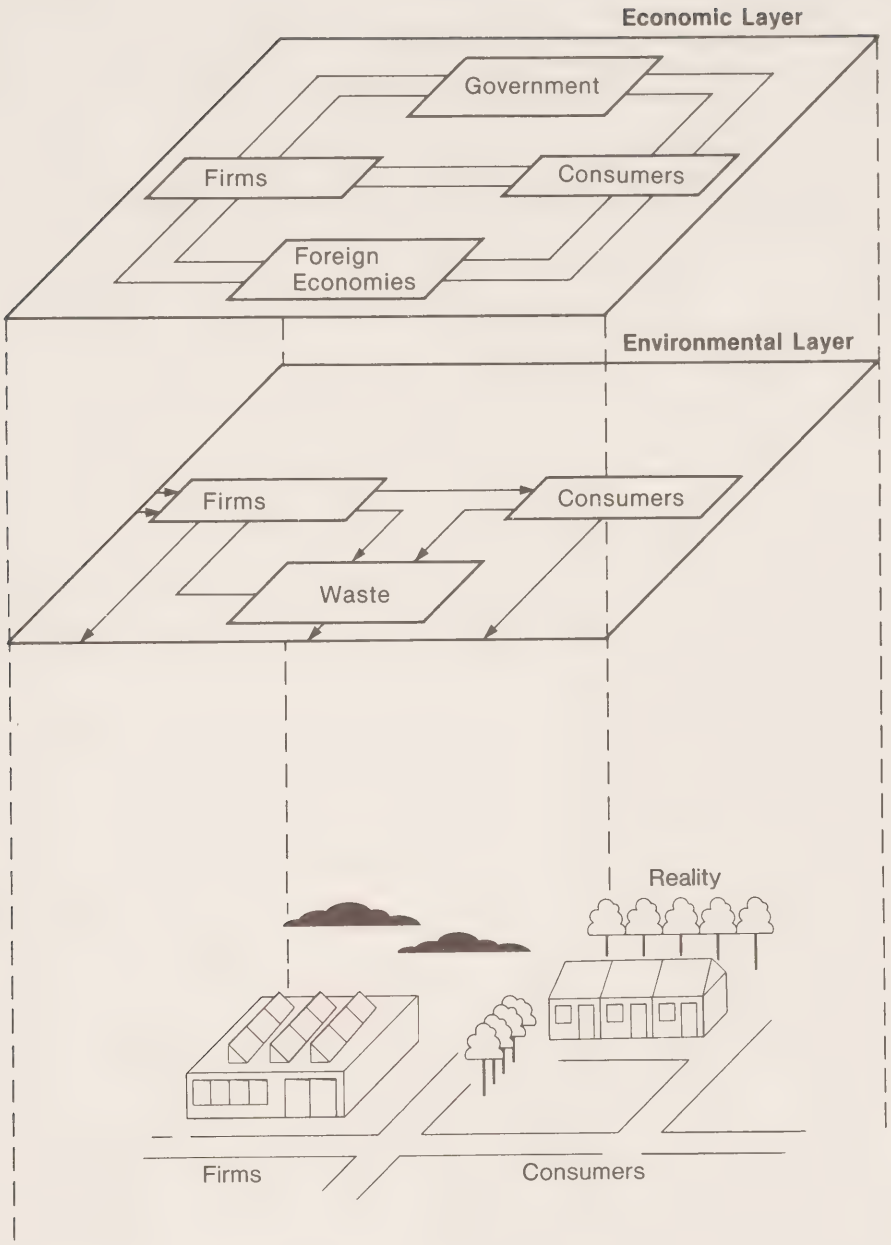


FIGURE 16
Economic-Environmental Model of a Spatial System
as a Result of Multi-Layer Projection
(from Hafkamp (1984))

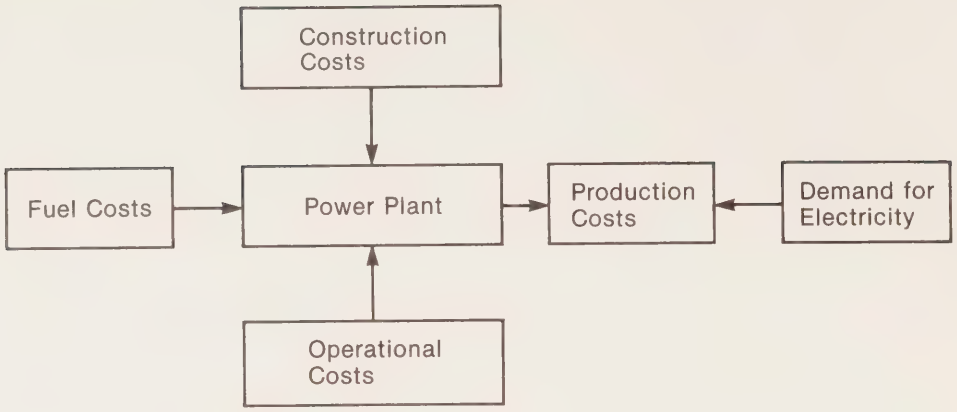


FIGURE 17
An Economic Model of a Power Generating System

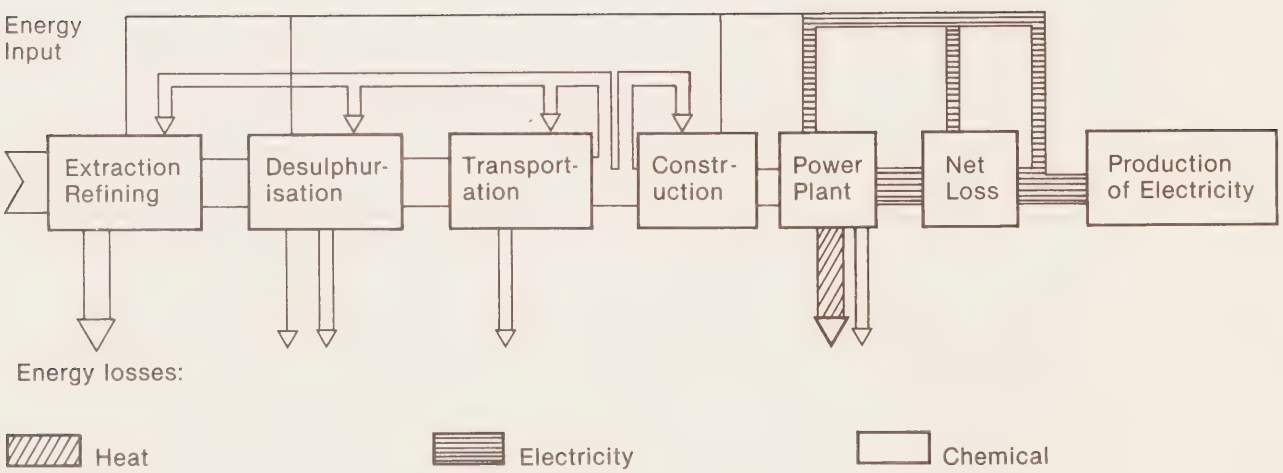


FIGURE 18
Energy Balance of a Power Generating System

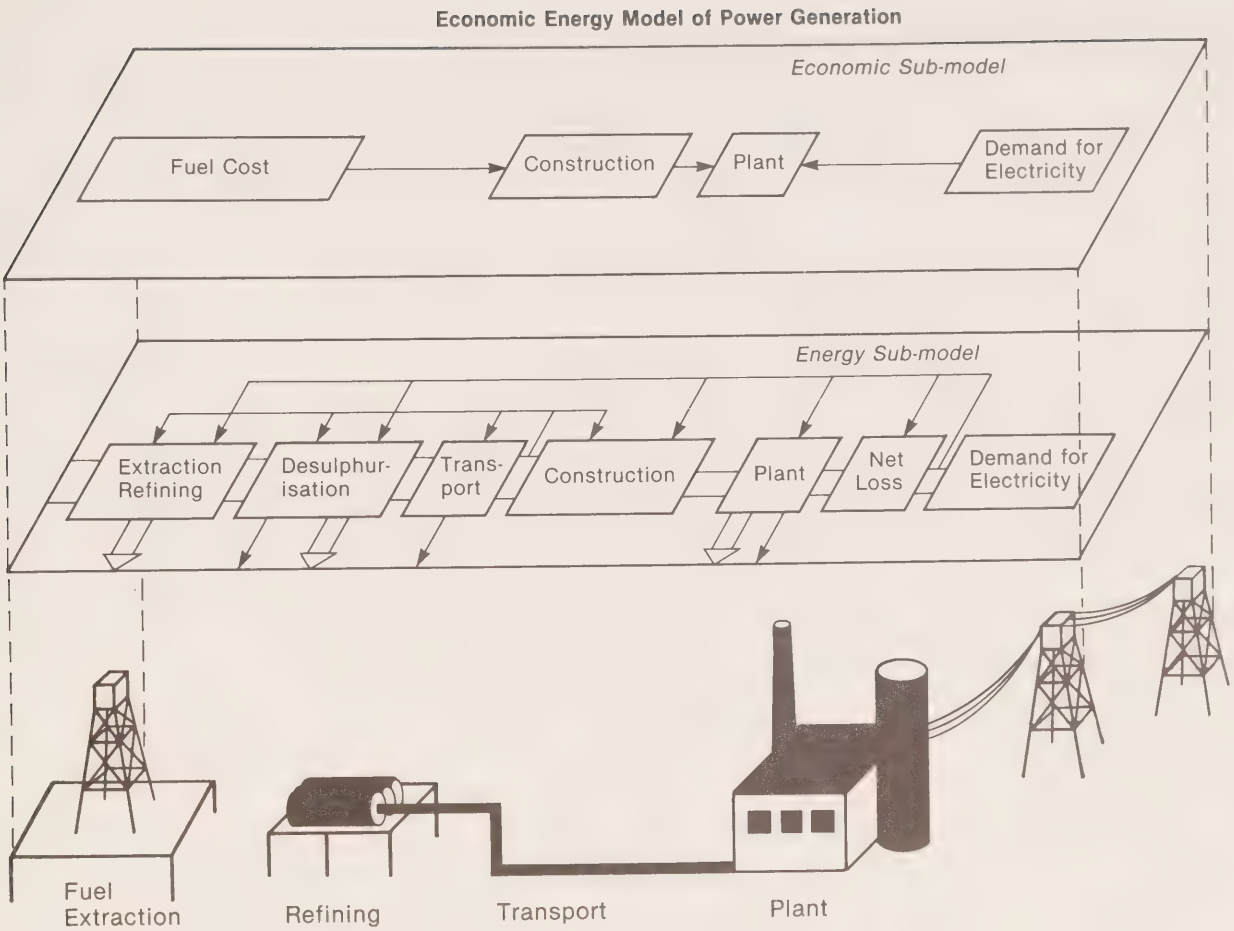


FIGURE 19
Economic Energy Model of a Power Generating System As a Result of Multi-Layer Projection
(Hafkamp 1984)

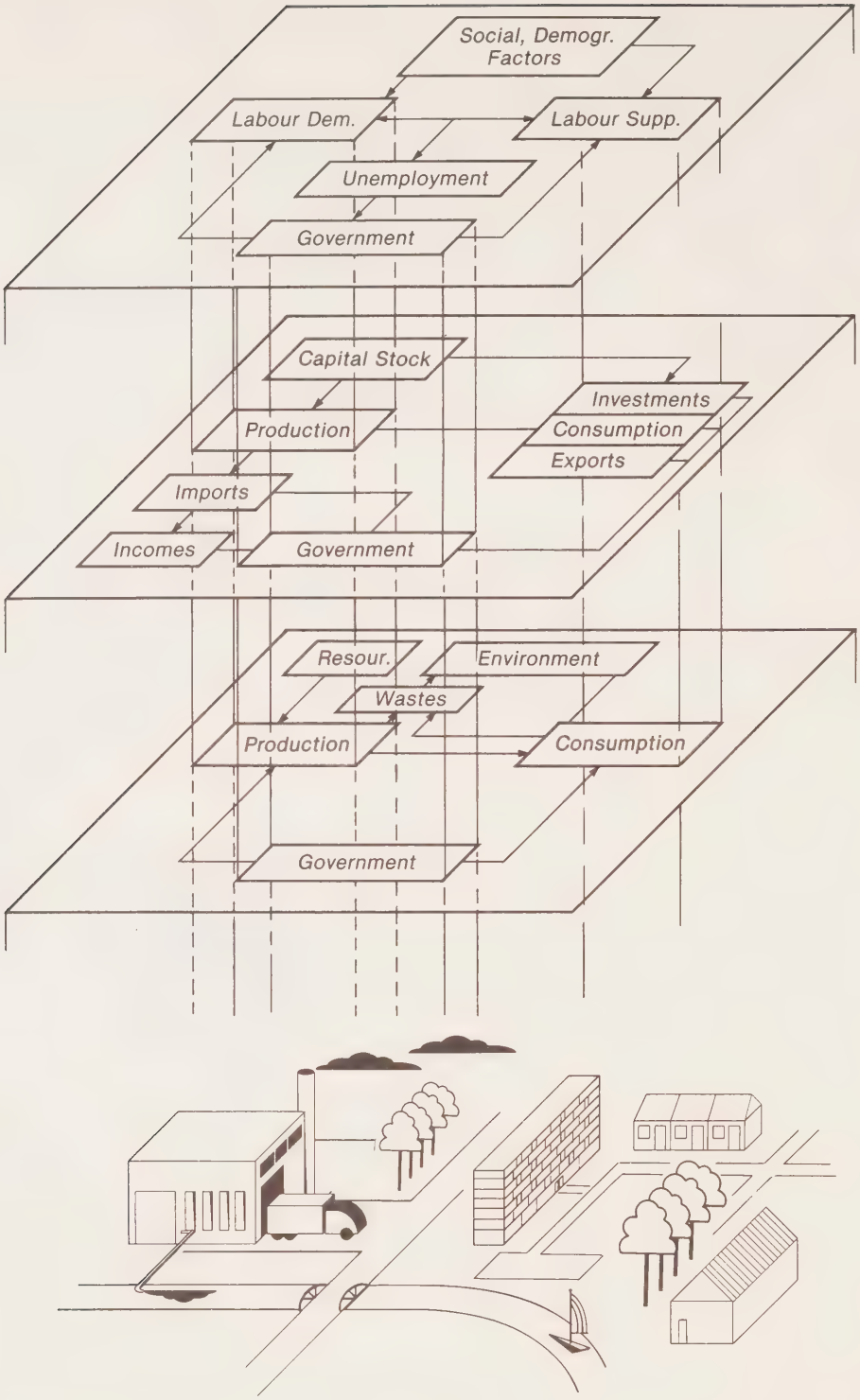


FIGURE 20
Simple Version of the Triple Layer Model
Obtained by Multi-Layer Projection
(from Hafkamp 1984)

THE RESULTS OF THE DATABASE SEARCHES

A number of database searches were completed to test availability of data on the general subject of environment-economy relationships, and on specific linkages. In this trial run, searches were completed on the following databases:

— *Economic Index*

— *Enviroline*

— *Magazine Index*

— *NTIS*

— *Environment Canada Library*

— *Pollution Abstracts*

Because of cost and volume considerations, print-outs of all identified material were not requested, and even the partial print-outs which were obtained were too voluminous to be reproduced in this report. This annex therefore contains a list of the searches undertaken along with particularly pertinent information including: subject matter, database, number of entries identified, and number of entries requested in the print-out.

In addition, the results of two database searches have been included for their reference value, and as an indication of the search procedure. The two samples which have been included are:

Search 1: Economic Index; Environment-Economy Relations; 101 of 101 entries identified.

Search 8: Enviroline; Air Pollution Effects on Building Values and Maintenance Costs; 20 of 40 entries identified.

Photo-copies of the print-outs from other searches, as listed below, can be made available on request to researchers who want to follow-up on specific aspects of this subject.

List of Sample Searches

Search No.	*Database*	*Subject*	*Entries Requested Identified*
1	Economic Index	Envir.-Economy Relations	101/101
2	Enviroline	" " "	5/5
2A	Enviroline	" " "	10/120
2A (cont.)	Enviroline	" " "	20/20
2B	Enviroline	" " "	5/334
3	Magazine Index	" " "	10/23
4	NTIS	" " "	10/4170
5	Envir. Canada Library	" " "	10/44
5A	Envir. Canada Library	" " "	20/229
6	Enviroline	Economics of Soil Erosion	2/2
6 (cont.)	Enviroline	" " "	5/319
6 (cont.)	Enviroline	" " "	5/73
6 (cont.)	Enviroline	" " "	5/10
6 (cont.)	Enviroline	" " "	6/6
6 (cont.)	Enviroline	" " "	10/338
6 (cont.)	Enviroline	" " "	8/8
6 (cont.)	Enviroline	" " "	4/9
7	Envir. Canada Library	Air Pollution Effects on Building Values & Maintenance Cost	20/40
8	Enviroline	" " "	5/5
9	Pollution Abstracts	Economic Effects of Mine Waste	20/119
10	Enviroline	Economic Effects of Acid Rain	20/28
11	Enviroline	" " "	20/22
12	Magazine Index	Effects of Forest Harvesting	
13	Enviroline	Policy on Fisheries and Fishing Industry	13/13

Search 1: Economic Index

Questions — Descriptors		No. of References
1. References to:	Environment	734
	Ecology	40
	Common Property Resource	8
	Pollution	1,662
2. References to:	Economic	45,453
	Economy	2,772
3. References to:	1. and 2.	731
4. References to:	Costs	4,920
	Interrelationship	38
	Relationship	1,301
	Link/Linkage	254
	Tie	107
	Effect	4,324
	Impact	2,519
5. Reference to:	1. and 2. and 3.	101

Print 1 — 101. (See following pages).

Note: Data on the attached pages have been reproduced from computer printouts.

135808
Alternative Mortgage Instruments: Their Effects on Consumer Housing Choices in an Inflationary Environment
Alm, James; Follain, James R., Jr.
Public Finance Quarterly, April 1982, 2, 134-57
Geographic Location: U.S.
Descriptors: credit to business, consumer, etc. including mortgages — mortgage market (3152); Housing Economics including nonurban housing (9320)

146917
Marketable Pollution Permits and Acid Rain Externalities
Atkinson, Scott E.
Canadian Journal of Economics, November 1983, 16 4. 704-22
Geographic Location: U.S.; Canada
This paper examines the economic implications of currently proposed marketable pollution right (MPR) systems for attaining ambient air quality standards in local airsheds. The author shows that (1) the magnitude of local control costs for one MPR system must be less than or equal to that under the current pollution control system and (2) if this MPR system significantly reduces local costs of control it must significantly increase local ambient degradation and, with high probability, the extent of long-range sulfate (S04) deposition. A simulation for a region of the Ohio River Basin indicates that the cost saving and increased ambient degradation and sulfate deposition in the Northeast and Canada should be large.
Descriptors: conservation and pollution (7220); regional economics — regional economic studies (9412)
abstract in JEL

150032
Some Comments Relating to Model Specification on "Effects of Nuclear Plants on Residential Property Values."
Bjornstad, David J.; Vogt, David P.
Journal of Regional Science, February 1984, 24 1, 135-36
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Housing Economics including nonurban housing (9320)

109587
New Standards for Strip Mining: Social, Economic and Environmental Costs Now Considered
Bonnefoy, Linda
Natural Resources Journal, October 1978, 18 4, 909-12
Geographic Location: U.S.
Descriptors: industry studies, extractive industries — mining metal, coal, and other nonmetallic minerals (6322); conservation and pollution (7220)

124805
Mieszkowski and Saper's Estimate of the Effects of Airport Noise on Property Values: A Comment
Borins, Sandford F.
Journal of Urban Economics, January 1981, 9 1, 125-28
Geographic Location: Canada
Descriptors: Economics of Transportation (6150); industry studies, services and related industries — real estate (6357); conservation and pollution (7220): Housing Economics including nonurban housing (9320)

064678
Comments on "Empirical Study of Economic-Ecologic Linkages in a Coastal Area" by J. C. Hite and E. A.
Laurent Bromley, Daniel W.; Meyer. Neil L.
Water Resources Research, October 1972, 8 5, 1361-63
Descriptors: regional economics — regional economic studies (9412): conservation and pollution (7220)

107250
The Effect of Air Pollution upon Mortality: A Consideration of Distributed Lag Models: Comment
Brown, Byron W., Jr.
Journal of the American Statistical Association, September 1978, 73 363, 472
Descriptors: conservation and pollution (7220); Demographic Economics (8410)

147418
Effects of Dynamic Task Environment on the Learning of Standard Cost Variance Significance
Brown, Clifton
Journal of Accounting Research, Autumn 1983, 21 2, 413-31
Geographic Location: U.S.
Descriptors: Managerial Economics (5120); Accounting (5410)

137912
The Effect of Air Pollution on Residential Location Decisions in Metropolitan Areas
Burnell, James D.
Regional Science Perspectives. 1981, 11 2, 3-14
Geographic Location: U.S.
Descriptors: conservation and pollution (7220): Urban Economics and Public Policy (9310); Housing Economics including nonurban housing (9320)

062127
Intercity Bus Transport in West Pakistan. Entrepreneurs in an Environment of Uncertainty
Burns, Robert E.
Journal of Transport Economics and Policy, September 1971, 5 3, 314-43

Geographic Location: Pakistan
Descriptors: Market Structure, Industrial Organization and Corporate Strategy (6110): Economics of Transportation (6150); Public Utilities and Costs of Government Regulation of Other Industries Private Sector (6130)
abstract in JEL

063692
Impact of the Changing Economic and Social Environment on Managers of Agricultural Firms
Candler, Wilfred
American Journal of Agricultural Economics, December 1971, 53 5, 870-77
Geographic Location: U.S.
Descriptors: Goals and Objectives of Firms (5140); agricultural marketing and agribusiness (7150)

132175
The Impact on Housing Costs of the California Coastal Zone Conservation Act
Case, Fred E.; Gale, Jeffrey
American Real Estate and Urban Economics Association Journal Winter 1981, 9 4, 345-66
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Urban Economics and Public Policy (9310); Housing Economics including nonurban housing (9320)

124407
The Relative Efficiency of Public and Private Firms in a Competitive Environment: The Case of Canadian Railroads
Caves, Douglas W.; Christensen, Laurits R.
Journal of Political Economy, October 1980, 88 5, 958-76
Geographic Location: Canada
Descriptors: Public Utilities and Costs of Government Regulation of Other Industries Private Sector — Regulation of Public Utilities (6131); Economics of Transportation (6150) abstract in JEL

139417
The Health Effects of Air Pollution: A Reanalysis
Chapple, Mike: Lave, Lester
Journal of Urban Economics, November 1982, 12 3, 346-76
Descriptors: conservation and pollution (7220); Demographic Economics (8410): Economics of Health (9130)

134146
The Cost of Automobile Safety and Emissions Regulation to the Consumer; Some Preliminary Results
Crandall, Robert W.; Keeler, Theodore E.; Lave, Lester B.
American Economic Review, May 1982, 72 2, 324-27
Geographic Location: U.S.
Descriptors: Industry Studies, Manufacturing — transportation and communication equipment (6314): conservation and pollution (7220): consumer economics, levels and standards of living — Consumer Protection (9213)

104222
Effects of Selected Changes in the Institutional and Human Environment upon output Per Unit of Input
Denison, Edward F. Survey of Current Business, January 1978, 58 1, 21-44
Geographic Location: U.S. Descriptors: Productivity and Growth, Theory and Data (2260); conservation and pollution (7220); Public Policy, Role of Government — Factory Act and Safety Legislation (8223); economics of crime (9160)

088846
Economic Growth and Environmental Deterioration-Some Aspects of Their Inter-Relationship
Dholakia, Bakul H.
Artha-Vikas, July-December 1978, 12 2, 54-63
Descriptors: conservation and pollution (7220); economic development models and theories (1120)

075768
Economic Study of the Effect of Municipal Sewer Surcharges on Industrial Wastes and Water Usage
Elliott, Ralph D.
Water Resources Research, October 1973, 9 5, 1121-31
Geographic Location: U.S.
Descriptors: conservation and pollution. (7220): Public Utilities and Costs of Government Regulation of Other Industries Private Sector (6130)

111873
The Effect of Water quality on Rural Nonfarm Residential Property Values
Epp, Donald J.; Al-Ani. K. S.
American Journal of Agricultural Economics, August 1979, 61 3, 529-34
Geographic Location: U.S.
Descriptors: rural economics (7180); conservation and pollution (7220)

153286
Cross-Compliance for Erosion Control: Anticipating Efficiency and Distributive Impacts
Ervin, David E.; Heffernan, William D.; Green, Gary P.
American Journal of Agricultural Economics, August 1984, 66 3, 273-78
Geographic Location: U.S.
Despite increasing attention, the effects of using differential agricultural program benefits to achieve soil conservation are largely unexplored. Viewed in a conventional environmental economics framework, the popularly perceived cross-compliance program may fall short on efficiency grounds. Analysis suggests that the greatest incentive to practice conservation may occur on land with little or no net social benefits forthcoming from erosion control. A by-product of cross-compliance worth consideration is that those likely to benefit most from the program are the highest equity and largest farm operators.
Descriptors: land reform and land use — land development, land use, irrigation policy (7172); conservation and pollution (7220) abstract in JEL

078086
A Probabilistic Cost Analysis of Two Stack Flue Gas Desulfurization Systems
Ezzati, Ali
Engineering Economist, January-February 1974, 19 2, 63-85
Descriptors: Managerial Economics (5220); conservation and pollution (7220)

133245
Patterns in the Laws on Health Risks
Field, Robert I.
Journal of Policy Analysis and Management, Winter 1982, 1 2, 257-60
Geographic Location: U.S.
Descriptors: Public Utilities and Costs of Government Regulation of Other Industries Private Sector (6130); conservation and pollution (7220); Economics of Health (9130)

064383
Impact of Population on Resources and the Environment
Fisher, Joseph L.
American Economic Review, May 1971, 61 2, 392-98
Geographic Location: U.S. Descriptors: Demographic Economics (8410): natural resources (7210): conservation and pollution (7220)

150033
Some Comments Relating to Model Specification on "Effects of Nuclear Power Plants on Residential Property Values"; Reply
Gamble, Hays B.; Downing, Roger H.
Journal of Regional Science, February 1984, 24 1, 137-38
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Housing Economics including nonurban housing (9320)

139400
Effects of Nuclear Power Plants on Residential Property Values
Gamble, Hays B.; Downing. Roger H.
Journal of Regional Science, November 1982, 22 4, 457-78
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Housing Economics including nonurban housing (9320)
abstract in JEL

117527
Socioeconomic Effectiveness of New Technology (Methodological Questions).
Gatovskii, L.
Problems of Economics, June 1979, 22 2, 39-58
Geographic Location: U.S.S.R.
Descriptors: socialist and communist economic systems (0520);
Technological Change, Innovation, Research and Development — Technological Change and Innovation (6211); conservation and pollution (7220)

086042
An Evaluation of the Impact of Aircraft Noise on Property Values with a Simple Model of Urban Land Rent
Gautrin, Jean-Francois
Land Economics, February 1975. 51 1, 80-86
Descriptors: conservation and pollution (7220); Urban Economics and Public Policy (9310); regional economics — regional economic studies (9412); Housing Economics including nonurban housing (9320)

151861
The Development and Impact of an EEC Directive: The Control of Discharges of Mercury to the Aquatic Environment
Guruswamy, L. D.; Papps, I.; Storey. D. J.
Journal of Common Market Studies, September 1983, 22 1, 71-100
Geographic Location: EEC: U.K.
Descriptors: Economic Integration — Economic Integration, Policy and Empirical Studies (4233); conservation and pollution (7220)

151582
A Model for Forecasting the Economic and Environmental Impact of Energy Policy
Harris, Curtis C.; McConnell, Virginia D.; Cumberland, John H.
Energy Economics, July 1984, 6 3, 167-76
Geographic Location: U.S.
Descriptors: Economic Forecasting and Econometric Models — Specific Forecasts and Models (1323); Input-Output (2220); conservation and pollution (7220); energy (7230)

112526
The Economic Impacts of Environmental Regulations on the U.S. Copper Industry
Hartman, Raymond S.; Bozdogan, Kirkor; Nadkarni, Ravindra M.
Bell Journal of Economics Geographic Location: U.S.
Descriptors: Industry Studies, Manufacturing — Metals iron, steel, and other (6312); conservation and pollution (7220)

152067
A Geobased National Agricultural Policy for Rural Community Enhancement, Environmental Vitality, and Income Stabilization
Hayden, F. Gregory
Journal of Economic Issues, March 1984, 18 1, 181-221
Geographic Location: U.S.
The article concludes that agricultural policy: should include site specific environmental policy to prevent soil erosion, water pollution, and wetland destruction, should reverse the policy-induced trend of rural community destruction, must take into consideration the impact of technology on farm and community structure, and must protect farm income and control production by allowing smaller farmers to plant a greater percent of land than larger farmers. Surplus production allows us to remove fragile land from production rather than promoting exports. The current financial, environmental, and structural disarray in agriculture offers real opportunity for improving the welfare of farmers and the people in general.
Descriptors: agricultural policy, domestic and international (7130); land reform and land use — land development, land use, irrigation policy (7172); rural economics (7180): conservation and pollution (7220)
abstract in JEL

065778
The Effect of Ecologically Relevant Information on Detergent Sales
Henion, Karl E.
Journal of Marketing Research, February 1972, 9 1, 10-14
Descriptors: conservation and pollution (7220); Marketing and Advertising (5310); Industry Studies, Manufacturing — chemicals, drugs, plastics, ceramics, glass, and rubber (6315): consumer economics, levels and standards of living — Expenditure Patterns and Consumption ST of Expenditure on Specific Items (9212)
abstract in JEL

149683
Planning for Institutional Change in a Complex Environment An Approach and an Application
Hickerson, Steven R.
Journal of Economic Issues, September 1983, 17 3, 631-65
Unified Program Planning, a systems approach technique developed by J. Douglas Hill and John N. Warfield, is applied to the ameliorative redesign of institutional arrangements, a process of long standing concern in institutional economics. The delivery of legal services is used as a vehicle in illustrating this application. The technique incorporates problem definition, value system design, and system synthesis stages, all of which are developed in a series of graphs and matrices. This culminates in a set of linked matrices, which depicts interactions among the elements of a complex system, and which facilitates the planning of incremental change in such a system.
Descriptors: history of economic thought — historical and institutional (0318); economic planning theory and policy — economic planning theory (1132)
abstract in JEL

064679
Empirical Study of Economic-Ecologic Linkages in a Coastal Area: Reply
Hite, James C.; Laurent. Eugene A,
Water Resources Research, October 1972, 8 5, 1364-65
Descriptors: regional economics — regional economic studies (9412); conservation and pollution (7220)

061473
Empirical Study of Economic-Ecologic Linkages in a Coastal Area
Hite, James C.; Laurent, Eugene A.
Water Resources Research, October 1971, 7 5, 1070-78
Geographic Location: U.S.
Descriptors: regional economics — regional economic studies (9412): conservation and pollution (7220)

100506
The Effects of Pollution Taxation on the Pattern of Resource Allocation: The Downstream Diffusion Case
Hochman, Eithan; Pines, David; Zilberman, David
Quarterly Journal of Economics, November 1977, 91 4, 625-38
Descriptors: national taxation and subsidies (3230); conservation and pollution (7220); regional economics — theory of regional economics (9411)
abstract in JEL

095143
Environmental Impact Evaluation, Land Use Planning, and the Housing Consumer
James, Franklin J.; Muller, Thomas
American Real Estate and Urban Economics Association Journal Fall 1977, 5 3, 279-301
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Housing Economics including nonurban housing (9320); regional economics (9410)

060794
Economic Analysis of Sewer Service Charge Formulas
Johnson, J. A.
Land Economics, February 1971, 47 2, 80-86
Descriptors: conservation and pollution (7220); Public Utilities and Costs of Government Regulation of Other Industries Private Sector (6130)
abstract in JEL

126436
Regional Environmental and Economic Impact Evaluation: An Input-Output Approach
Johnson, Manuel H.; Bennett, James T.
Regional Science and Urban Economics, May 1981, 11 2, 215-30
Descriptors: conservation and pollution (7220); regional economics — regional economic models and forecasts GENERAL) (9413)

116643
An Input-Output Model of Regional Environmental and Economic Impacts of-Nuclear Power Plants
Johnson, Manuel H.; Bennett, James T.
Land Economics, May 1979, 55 2, 236-52
Geographic Location: U.S.
Descriptors: industry studies, services and related industries — electrical, gas, communication, and information services (6352); conservation and pollution (7220); regional economics — regional economic studies (9412)
abstract in JEL

057673
Environmental Disruption and Social Costs: A Challenge to Economics
Kapp, K. William
Kyklos, 1970, 23 4, 833-48
Descriptors: welfare theory — externalities (0244); economic methodology (0360)

014780
Rent Relationships in the Economic Mechanism of Social Production
Kassirov, L.
Problems of Economics, November 1973, 16 7, 36-58
Descriptors; socialist and communist economic systems (0520); conservation and pollution (7220)

154014
Faculty Advancement in a Nontraditional University Environment
Kaun, David E.
Industrial and Labor Relations Review, July 1984, 37 4. 592-606
This study examines faculty advancement rates during the formative years of the University of California, Santa Cruz. An explicit goal of the administration was to obtain high-quality undergraduate teaching from faculty members who were to be appraised on the basis of criteria that emphasize research. Previous studies of faculty advancement have shown little or no reward for high-quality teaching, but this study finds e significant relationship between faculty advancement and quality teaching, in addition to the usual relationship with length of service and publications. The author concludes that the institutional environment can influence the faculty reward structure to promote improved teaching.
Descriptors: occupation (8120); Labor Market Studies, Wages, Employment — Wage and Fringe Benefit Studies (8242): Economics of Education (9120)
abstract in JEL

099913
The Impact of Development on the Environment
Kerr, Derek
National Westminister Bank Quarterly Review, August 1977.
Geographic Location; U.K.
Descriptors: economic studies of developed countries — European countries (1223); conservation and pollution (7220)

073484
The Effect of Ecological Concern on Brand Perceptions
Kinnear, Thomas C.; Taylor, James R.
Journal of Marketing Research, May 1973, 2, 191-97
Geographic Location: U.S.
Descriptors: Marketing and Advertising (5310); conservation and pollution (7220); consumer economics, levels and standards of living — Expenditure Patterns and Consumption ST of Expenditure on Specific Items (9212)

065853
Effective Pollution Control in Industrialized Countries: International Economic Disincentives, Policy Responses, and the GATT
Kirgis, Frederic L., Jr.
Michigan Law Review, April 1972. 5, 859-918
Descriptors: conservation and pollution (7220); Commercial Policy and Trade Regulations, Empirical Studies (4220)

124971
An Economic Analysis of "Pollution Control Public Works Cost Allocation Law". (In Japanese.)
Kishimoto, Tetsuya
Kokumin-Keizai Zasshi, December 1980, 142 6, 83-94

126399
Environmental Regulation and Optimal Investment Behavior: A Micro-Economic Analysis
Kopp, Raymond J.; Smith, V. Kerry
Regional Science and Urban Economics, June 1980, 2. 211-24
Descriptors: Business Investment (5220); Public Utilities and Costs of Government Regulation of Other Industries Private Sector (6130); conservation and pollution (7220)

108284
Community Environment snd the Market Value of Single-Family Homes: The Effect of the Dispersion of Land Uses
Lafferty, Ronald N.; Frech, H. E., III
Journal of Law and Economics, October 1978, 21 2. 381-94
Descriptors: Urban Economics and Public Policy (9310); Housing Economics including nonurban housing (9320)

153110
The Possible Impact of National Accounts and Balances on the Development of Frameworks for Environment Statistics
Laganier, Jean
Statistical Journal, January 1984, 2 1, 43-61
Descriptors: Economic and Social Statistical Data and Analysis (2200)

065810
Economic-Ecologic Linkages and Regional Growth: A Case Study
Laurent, Eugene A.; Hite, James C.
Land Economics, February 1972, 48 1, 70-72
Descriptors: Input-Output (2220); regional economics — regional economic models and forecasts (9413); conservation and pollution (7220)

135812
Housing Demand and the Standard Mortgage Instrument: Comment Alternative Mortgage Instruments: Their Effects on Consumer
Housing Choices in an Inflationary Environment Accelerating Inflation and Nonassumable Fixed-Rate Mortgages: Effects on Consumer Choice and Welfare.
Lea, Michael J. Public Finance Quarterly, April 1982, 2, 185-92
Geographic Location: U.S.
Descriptors: credit to business, consumer, etc. including mortgages — mortgage market (3152); Housing Economics including nonurban housing (9320)

102872
The Assessment of Environmental Impacts in Project Appraisal in the European Communities
Lee, Norman; Wood, Christopher
Journal of Common Market Studies, March 1978, 16 3, 189-210
Geographic Location: EEC
Descriptors: Economic Integration — Economic Integration, Policy and Empirical Studies (4233); conservation and pollution (7220)

067237
Die volkswirtschaftlichen Kosten des Umweltschutzes — Ein erweitertes Input-Output-System. (The Economic Costs of Depollution-An Enlarged Input-Output System. With English summary.)
Lehbert, Berndt
Weltwirtschaftliches Archiv, 1972, 8 2, 298-318
Descriptors: Input-Output (2220); conservation and pollution (7220)
abstract in JEL

120110
Measurement of the Socioeconomic Impact of Lake Restoration: An Assessment Model Employing a Benefit/Cost Cross-Impact Probabilistic Approach
Liu, Ben-chieh; Christiansen, Neils: Jaksch, John American Journal of Economics and Sociology, July 1980. 39 3. 227-36
Geographic Location: U.S.
Descriptors: natural resources (7210); conservation and pollution (7220); regional economics — regional economic studies (9412)

114242
Regional Estimates of the Morbidity Cost of Total Suspended Particulates
Liu, Ben-Chieh; Yu, Eden S. H.
Growth and Change, April 1980, 11 2, 26-31
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Demographic Economics (8410); regional economics — regional economic studies (9412)

115362
Distributional Analysis of Regional Benefits and Cost of Air Quality Control
Loehman, E. T., et al.
Journal of Environmental Economics and Management, September 1979, 6 3, 222-43
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); regional economics — regional economic studies (9412)

116679
A Preference Approach to Measuring the Impact of Environmental Externalities
Mark, Jonathan H.
Land Economics, February 1980, 56 1, 103-16
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Urban Economics and Public Policy (9310)

059428
Economic Efficiency Implications of Federal-Local Cost Sharing in Water Resource Development
Marshall, Harold Emory
Water Resources Research, June 1970, 6 3, 673-82
Geographic Location: U.S.
Descriptors: intergovernmental financial relationships (3250); conservation and pollution (7220)

108863
An Estimate of the Effects of Airport Noise on Property Values
Mieszkowski, Peter; Saper, Arthur M.
Journal of Urban Economics, October 1978, 5 4, 425-40
Geographic Location: Canada
Descriptors: Economics of Transportation (6150); industry studies, services and related industries — real estate (6357); conservation and pollution (7220); Housing Economics including nonurban housing (9320)

082604
The Economic Impact of Controlling Nonpoint pollution in Hardwood Forestland
Miller, W. L.; Everett, H. W.
American Journal of Agricultural Economics, November 1975, 57 4, 576-83
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); natural resources (7210) abstract in JEL

096133
Economic Environments for Which There Are Pareto Satisfactory Mechanisms
Mount, Kenneth; Reiter, Stanley Econometrica, May 1977, 45 4. 821-42
Descriptors: welfare theory — allocative efficiency including theory of cost/benefit (0242)
abstract in JEL

113417
The Impact of Decentralization on the Journey-to-Work and Pollution
Naroff, Joel L.; Ostro, Bart David
Economic Geography. January 1980, 58 1, 63-72
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Urban Economics and Public Policy (9310); urban transportation economics (9330)

126144
The 1977 Clean Air Act Amendments: Energy, Environmental, Economic, snd Distributional Impacts
Navarro, Peter
Public Policy, Spring 1981, 29 2, 121-46
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); energy (7230)

132178
Housing Costs and prices under Regional Regulation
Nicholas, James C.
American Real Estate and Urban Economics Association Journal Winter 1981, 9 4, 384-96
Geographic Location: U.S.
Descriptors: land reform and land use — land development, land use, irrigation policy (7172); conservation and pollution (7220); Housing Economics including nonurban housing (9320)

152447
Coevolutionary Development Potential
Norgaard, Richard B. Land Economics, May 1984, 2, 160-73
In biology, "coevolutionary" refers to an evolutionary process based on reciprocal responses between two closely interacting species. The concept can be broadened to encompass any ongoing feedback process between two evolving systems, including social and ecological systems. This paper presents several ideas new to economics; among them are: (1) The neoclassical view of economic development as a process of augmenting factors of production stems from the basic assumption that factors are separable. However, a harmony-with-nature world view has provided much of the philosophical and scientific basis for resource and environmental policies. (2) The coevolutionary perspective gives a better picture of the nature of the social and ecological problems that accompany the factor-augmentation approach to development. (3) Few people today doubt the efficiency of the market except with respect to environmental management and intertemporal natural resource allocation. The coevolutionary model incorporates relationships between people and their environments based on recent advances in the natural sciences and is thereby more appropriate over the long run for exploring the relationship between resources, environmental systems, and social systems.
Descriptors: economic development models and theories (1120); natural resources (7210); conservation and pollution (7220)
abstract in JEL

104651
Regional Economic Impacts of Policies to Control Erosion and Sedimentation in Illinois and Other Corn Belt States
Osteen, Craig; Seitz, Wesley D.
American Journal of Agricultural Economics, August 1978, 3, 510-17
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); regional economics — regional economic studios (9412)
abstract in JEL

147603
The Effects of Air Pollution on Work Loss and Morbidity
Ostro. Bart D.
Journal of Environmental Economics and Management, December 1983, 4, 371-82
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Economics of Health (including medical subsidy programs) (9130)

137321
The Secondary Impact of Nonpoint-Pollution Controls: A Linear-Programming-Input/Output Analysis
Palmini, Dennis J.
Journal of Environmental Economics and Management, September 1982, 9 3, 263-78
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); regional economics — regional economic studies (9412)

133387
Measuring Environmental Effects on Property Values without Hedonic Regressions
Palmquist, Raymond B.
Journal of Urban Economics, May 1982, 11 3, 333-47
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Housing Economics including nonurban housing (9320)

071637
The Impact of the Environment upon the Spatial Distribution of Population and Land Values
Papageorgiou, G. J.
Economic Geography, July 1973, 49 3, 251-56
Descriptors: economic geography (7310); Urban Economics and Public Policy (9310)

066159
Economic Aspects of Pollution Control
Parish, Ross M. Australian Economic Papers, June 1972, 11 18, 32-43
Descriptors: conservation snd pollution (7220); welfare theory — allocative efficiency including theory of cost/benefit (0242)
abstract in JEL

129256
Regulation and the Economy; Concluding Thoughts
Peskin Henry M.; Portney, Paul R.; Kneese, Allen V.
Natural Resources Journal July 1981, 21 3, 589-91
Geographic Location. U.S.
Descriptors: National Income Accounting Theory and Procedures (2210); Public Utilities and Costs of Government Regulation of Other Industries Private Sector — Effects of Regulation on Market Structure, Costs and Efficiency (6132); conservation and pollution (7220)

129251
The Macroeconomic Impacts of Federal Environmental Regulation
Portney, Paul R.
Natural Resources Journal, July 1981, 21 3, 459-88
Geographic Location: U.S.
Descriptors: Economic Forecasting and Econometric Models — Specific Forecasts and Models (1323); Public Utilities and Costs of Government Regulation of Other Industries Private Sector — Effects of Regulation on Market Structure, Costs and Efficiency (6132); Industry Studies, Manufacturing (6310); conservation and pollution (7220)

123763
Housing Prices, Health Effects, and Valuing Reductions in Risk of Death
Portney, Paul R. Journal of Environmental Economics and Management, March 1981, 8 1, 72-78
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Economics of Health (9130); Housing Economics including nonurban housing (9320)

073815
Minimizing Losses in a Hostile Environment: The Costs of Defending One's Castle
Prohaska, Charles R.; Taylor, Walton
Journal of Risk and Insurance. September 1973, 3, 375-87
Descriptors: economics of crime (9160)

129255
Long-Run Effects of Environmental Regulation
Ridker, Ronald G.; Watson, William D.
Natural Resources Journal, July 1981, 21 3, 565-87
Geographic Location: U.S.
Descriptors: Economic Forecasting and Econometric Models — Specific Forecasts and Models (1323); Public Utilities and Costs of Government Regulation of Other Industries Private Sector — Effects of Regulation on Market Structure, Costs and Efficiency (6132); conservation and pollution (7220)

101396
The Effect of Urban Structure on the Concentration of Pollution
Robson, Arthur J.
Urban Studies, February 1977, 14 1, 89-93
Geographic Location: U.S.
Descriptors: Urban Economics and Public Policy (9310); conservation and pollution (7220)

147757
Modeling the Macroeconomic Impact of Air Pollution Abatement
Rose, Adam
Journal of Regional Science, November 1983, 23 4, 441-59
Geographic Location: U.S.
A critical evaluation of the literature indicates that there is no definitive conclusion on whether the net economic impact of air pollution regulations is positive or negative. Each study on the subject has omitted several causal factors and failed to provide empirical justification for many of its assumptions. This paper presents a model framework for assessing the national or regional impact of pollution abatement that is able to incorporate a broader and more flexible set of causal relationships. An application of the model illustrates the sensitivity of net impacts to alternative specifications of investment displacement, cost pass-through, and government spending relationships.
Descriptors: conservation and pollution (7220); regional economics — regional economic studies (9412)
abstract in JEL

129212
Economic Theory and Environmental Law
Sagoff, Mark
Michigan Law Review, June 1981, 79 7, 1393-1419
Descriptors: welfare theory — allocative efficiency including theory of cost/benefit (0242); conservation and pollution (7220)

092076
A Regional Analysis of Air Quality Standards, Coal Conversion, and the Steam-Electric Coal Market
Schlottmann, Alan
Journal of Regional Science, December 1976. 16 3. 375-87
Geographic Location: U.S.
Descriptors: regional economics — regional economic studies (9412); conservation and pollution (7220); natural resources (7210); Public Utilities and Costs of Government Regulation of Other Industries Private Sector (6130)
abstract in JEL

070651
Solid Waste Management for Rural Areas: Analysis of Costs and Service Requirements
Schreiner, Dean; Muncrief, George; Davis, Bob American
Journal of Agricultural Economics, Part I, November 1973, 55 4, 567-76
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); rural economics (7180)
abstract in JEL

109175
Economic Impacts of Soil Erosion Control
Seitz, Wesley D., et al.
Land Economics. February 1979, 55 1, 28-42
Geographic Location: U.S.
Descriptors: conservation and pollution (7220)
abstract in JEL

108893
An Analysis of Some Short-Term Health Effects of Air Pollution in the Washington. D.C. Metropolitan Area
Seskin, Eugene P.
Journal of Urban Economics. July 1979, 6 3, 275-91
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); Economics of Health (9130)

108847
The Environmental Impact of Transport and the Public Interest
Sharp, Clifford D.
Journal of Transport Economics and Policy, January 1979, 13 1, 88-101
Descriptors: welfare theory (0240); Economics of Transportation (6150)
abstract in JEL

103540
The Effects of Mercury Contamination in Pheasants on the Value of Pheasant Hunting in Oregon
Shulstad, Robert N.; Stoevener, Herbert H.
Land Economics, February 1978, 54 1, 39-49
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); consumer economics, levels and standards of living (9210)

099211
Estimating the Air Pollution Costs of Transport Modes
Small, Kenneth A. Journal of Transport Economics and Policy. May 1977, 11 2, 109-32
Geographic Location: U.S.
Descriptors: Economics of Transportation (6150); conservation and pollution (7220)
abstract in JEL

084773
Mortality-Air Pollution Relationships: A Comment
Smith, V. Kerry
Journal of the American Statistical Association, June 1975 341-43
Geographic Location: U.S.
Descriptors: Demographic Economics (8410); conservation and pollution (7220)
abstract in JEL

085873
Measuring the Impact of Air Pollution on Property Values
Smith, V. Kerry; Deyak, Timothy A.
Journal of Regional Science, December 1975, 15 3, 277-88
Geographic Location: U.S.
Descriptors: Housing Economics including nonurban housing (9320); conservation and pollution (7220)
abstract in JEL

072938
Effectiveness of Two Technical Assistance Efforts in Differing Environments
Stoner, James A. F.; Aram, John D.
Journal of Development Studies, July 1973, 9 4, 508-17
Descriptors: International Aid (4430); economic studies of developing countries (1210)

076029
The Ex-Slave in the Post-Bellum South; A Study of the Economic Impact of Racism in a Market Environment
Sutch, Richard; Ransom, Roger
Journal of Economic History, March 1973, 33 1, 131-48
Geographic Location: U.S.
Descriptors: economic history, North America excluding Mexico — history of factor prices and markets (0422); economics of minorities, economics of discrimination (9170)

129150
Avoidance Costs Associated with Imperfect Information: The Case of Kepone
Swartz, David G.; Strand Ivar E.,
Jr. Land Economics, May 1981, 57 2, 139-50
Geographic Location: U.S.
Descriptors: conservation and pollution (7220); consumer economics, levels and standards of living (9210)
abstract in JEL

078414
Economic Impact of Imposing Per Acre Restrictions on Use of Nitrogen Fertilizer in Illinois
Taylor, C. Robert; Swanson, Earl R.
Illinois Agricultural Economics. July 1974, 14 2. 1-5
Geographic Location: U.S.
Descriptors: agricultural supply and demand analysis (7110); conservation and pollution (7220)

142306
Aggregate Economic Effects of Alternative Boll Weevil Management Strategies
Taylor, C. Robert. et al.
Agricultural Economics Research. April 1983. 35 2. 19-28
Geographic Location: U.S.
Descriptors: agricultural supply and demand analysis (7110); conservation and pollution (7220)

109034
Gesamtwirtschaftliche Wirkungen der Umweltpolitik, (Economic Impact of Pollution Control Policies. With English summary.)
Tomann, Horst
Konjunkturpolitik. 1979. 25 1. 47-72
Geographic Location: W. Germany
Descriptors: conservation and pollution (7220)
abstract in JEL

078415
Economic Effects of a Total Farm Nitrogen Balance Approach to Reduction of Potential Nitrate Pollution
Walker, M. E.. Jr.; Swanson, Earl R.
Illinois Agricultural Economics, July 1974, 14 2, 21-27
Geographic Location: U.S.
Descriptors: agricultural supply and demand analysis (7110): conservation and pollution (7220)

076614
Micro Economic Environmental Impact Methodology
Ward, Richard J.
American Economist, Spring 1974, 18 1, 82-52
Descriptors: conservation and pollution (7220)

110049
Decision Making for Toxic Substances Control: Cost-Effective Information Development for the Control of Environmental Carcinogens
Weinstein, Milton C.
Public Policy, Summer 1979, 27 3, 333-83
Geographic Location: U.S.
Descriptors: Economics of Health (9130)

109790
Distributional Effects of Collectivs Goods
Weisbrod, Burton A.
Policy Analysis, Winter 1979, 5 1. 67-95
Descriptors: welfare theory (0240); social choice and bureaucratic performance (0250): conservation and pollution (7220); economics of minorities, economics of discrimination (9170); consumer economics, levels and standards of living — Consumer Protection (9213)

108833
Measuring the Costs of Noise Nuisance from Aircraft: A Review Article
Whitbred, Michael
Journal of Transport Economics and Policy. May 1978, 12 2, 202-08
Descriptors: Economics of Transportation (6150); conservation and pollution (7220)

107268
The Effect of Air Pollution Upon Mortality; A Consideration of Distributed Lag Models
Wyzga, Ronald E. Journal of the American Statistical Association, September 1978. 73 363, 463-72
Geographic Location: U.S.
Descriptors: conservation and pollution (7220): Demographic Economics (8410)

Search 8: Enviroline

Sample Problem 2: Air Pollution Effects on Building Values and Maintenance Costs

Questions — Descriptors		No. of References
1. References to:	Economy, Impact, Air Pollution	119
2. References to:	Air Pollution, Damage	990
3. References to:	Building	1,965
	Real Estate	409
	House	1,109
	Housing	1,533
4. Reference to:	(1. and 2.) and any of 3.	42
5. Reference to:	Indoor	432
6. Reference to:	Not indoor	40
7. Print first twenty references of 6.		

Note: Data on the attached pages have been reproduced from computer printouts.

0171674 *84-003583
Acid Rain Irritates Congress and Canada.
Dunne Nancy
Financial Times of London, Feb 17, 84. P4
Although Presiendt Ronald Reagan is urging Congress to increase funding levels for acid rain research, no effective clean-up program or acid rain control effort has been instituted. Canadian officials have criticized President Reagan's stance on the acid rain issue. The acid rain phenomenon has caused untold damage in Canada and the Northeastern U.S.. killing aquatic life. Eroding buildings and monuments. And damaging forests. Supporters of acid rain control legislation seek to impose emission controls on utilities and smokestack industries of the Midwestern U.S.
Descriptors: *acid rain : *transnational pollution ; *Canada *United States East; *air quality programs; *stack emission control; air pollution damage; econ impact-air poll
Review Classification: 01

0171598 *84-003507
Acid Deposition and the Materials Damage Question,
Scholle Stephen R.
Environment, Oct 83, V25, N8, P25 (8)
Journal article acidic air pollutants are the primary agents of weathering and corrosion of marble statuary. Buildings, and monuments, mechanisms of acid rain damage to materials are explained; sulfur dioxide and other acid gases diffuse through oxidation and solution products that form on common material surfaces in the presence of water. Related research addressing the extent of such damage, and implications for public health in light of lead leaching from pigments and masonry materials are examined. (4 photos, 44 references, 1 table)
Descriptors: *acid rain; *air pollution damage; *weathering; *erosion; *sulfur dioxide; *coatings; *heavy metals; corrosion; leaching; lead; historic sites
Review Classification: 01

0168049 *84-000007
Estimates of the National Benefits and Costs of Improving Ambient Air Quality,
Brady, Gordon L.; Bower Blair T.; Lakhani Hyder A. Yale Univ,
J Env Management, Apr 83. V16, N3, P49 (2)
Estimates of national benefits and costs of ambient air quality improvement in the U.S. for the period 1970-78 are examined. The literature on national benefits to health and non-health is critically reviewed. For the study period, the value of these benefits was in the range $5-51 billion, with a point estimate of about $22 billion. National costs estimates by CE, U.S. Bureau of Economic Analysis, and McGraw Hill are discussed and compared. National benefits for improving ambient air quality exceed the national costs for the average and the high values of the benefits, but not for the low estimates. (49 references, 2 tables)
Descriptors: *cost benef analysis-air; *air quality programs; *economics, env-air; *econ impact-air poll cont; *air poll cont investment; *air pollution damage; *death rates; *visibility; aesthetics, env; crop damage; particulates; real estate; capital costs; air quality criteria
Review Classification: 01

0167458 *83-006118
The New Politics of Acid Rain
Trisko Eugene M.
Coal Mining & Processing, Jul 83, V20, N6, P50 (5)
Acid rain legislation is pending before both Houses of Congress. The underlying political foundations of the acid rain issue were based on environmental concerns in the 1970s. The shape of the controversy appears to be changing as concerns about unemployment, coal market disruption, and high electric utility rate impacts from emission reduction requirements are spawning a new generation of control proposals. An overview of the causes and environmental impacts of acid rain is presented. Costs and benefits of control options are evaluated, and the new politics influencing emission reduction legislation is discussed. (6 references, 2 tables)
Descriptors: *acid rain; *legislation, env-fed; *stack emission control; *united states east; *cost benef analysis-air; *econ impact-air poll; *air pollution damage; *air quality stands; energy impact assessment; power plant emission control; pollution tax; lobbying, env-fed; economics, env-air; sulfur dioxide
Review Classification: 01

0166390 *83-005099
Restoring a Russian Heritage Turns Out to be a Byzantine Task.
Daniloff Ruth Smithsonian, Mar 83, v13. n12. p64 (12)
Soviet efforts to preserve their heritage by restoring palaces, churches, paintings, icons, an other historical treasures are chronicled. Many Russian leaders after Lenin have argued that art and architecture associated with religion should be eradicated, while Russianophiles claim that these are treasures of Soviet culture. Despite the Soviet government's initial attempts at preservation, restorers claim more work is needed. The government's planning commission has emphasized the industrial future over the cultural past. A new level of restoration skill must supplement traditional methods because of the effects of industrial pollution on many (cont. next page) buildings. Ninety-percent of Soviet art restorers are not trained in the latest techniques and can cause damage. (12 photos)
Descriptors: *historic sites; *USSR; *buildint design; *air pollution damage; *aesthetics, env; philosophical implictn env
Review Classification: 05

0165501 *83-004233

Acid Rain,

Boyle Robert H: Boyle R. Alexander Amicus J, Winter 83, V4, N3, P22 (16)

Feature article an overview of the acid rain phenomenon threatening the environments of Canada and the U.S. is presented. Acid rain is caused by the emission of 50-60 million tons of sulfur dioxide and nitrogen oxides from fossil fuel combustion. In the atmosphere, S02 and nox can be transformed into sulfuric acid and nitric acid and air currents can carry them thousands of miles from their source. When the acids fall to earth, they can have a devastating effect on lands and waters that have low natural buffering capacity. The impacts of acid precipitation on fish, human health, crops and forests, and buildings and monuments are discussed. Efforts being made by local, state, and the federal authorities to deal with this problem are examined. (1 diagram, 4 maps, 5 photos)

Descriptors: *acid rain; *air pollution damage; *fish kills; *heavy metals; *sulfur doxide; *nitrogen oxides; *transnational pollution; *policy-planning; crop damage; PH hydrogen ION concentratn; sulfuric acid; North America; atmospheric pollutant deposition; power plant emissions

Review Classification: 01

0165470 *83-004202

Reactions Between Vehicle Emissions and Building Materials,

Martin Keith G.

CSIRO.

Clean Air, Nov 82, V16, N4, P60 (6)

Technical feature mechanisms of potential reactions between air pollutants and building materials are reviewed. The review serves as a basis for estimating damage to buildings in Australian cities due to motor vehicle emissions. Reactions and degradation mechanisms considered include photooxidation, chalking, ozonolysis, deterioration of rubber and fabrics, Corrosion, erosion, and soiling are discussed. (42 references)

Descriptors. *automobile emissions; *buildings; *Australia; *air chemistry; *air pollution damage; *photodegradation; *corrosion; *erosion; *soiling index; particulates; ozone; zinc; coatings

Review Classification: 01

0162799 *03-001629

Conservation of Historic Stone Buildings and Monumrnyd (Some Illustrative Preservation Problems and Treatments in Washington, D.C.,)

Roth J. Walter

US General Services Admin, DC.

NAS/NATL Research Council Report, 1982, P31 (18)

Survey report in conjunction with a self-guided tour of historic stone buildings and monuments in Washington, DC, A diagrammatic map was prepared, noting the street locations of the subjects. Preservation problems, treatments, and evaluations for each structure are discussed. The aging and deterioration of historic buildings is attributed to staining and discoloration, weathering and pollution, or impacts of mineralization, vegetation, and pests. (1 map, 8 photos)

Descriptors: *Washington, DC; *historic sites; *landmark preservation; *aesthetics, env-urgan; *air pollution damage; weathering; pest control

Review Classification: 05

0162622 *83-001452

Conservation of Historic Stone Buildings and Monuments (Measurement of Local Climatological and Air Pollution Factors Affecting Stone Decay),

Tobach Ivar

Aerovironment, CA,

NAS/NATL Research Council Report, 1982, P197 (14)

Technical feature the atmosphere is a primary contributor to the decay of stone in historic buildings. These contributors range from the natural consequences of rainfall, wind frost, and heat to the complicated chemical and biological processed resulting from pollution. A list of such factors is broken down into these groups: available moisture in the form of rain, fog, and humidity; atmospheric temperature; the cooling and heating of surfaces by wind and radiation; evaporation and condensation on surfaces; the motion of air; and the presence of pollutants. Techniques for measuring parameters within each group have been developed, and can be applied to assist in research on stone preservation. (17 references, 3 tables)

Descriptors: *air pollution damage; *historic sites; *weathering; *humidity; *erosion, wind; *erosion, water; *armospheric pollutant deposition; *aerosols; fog; rainfall; solar radiation; nitrogen oxides; sulfur dioxide; atmospheric temperature

Review Classification: 01

0153410 *81-006203

Effects of Acid Precipitation in North America.

Glass, Norman R.; Glass Gary E.; Rennie Peter J. EPA. Ore, Env Intl, 1980, V4, N5&6, P443 (10)

Technical feature acid precipitation in North America has spread south- and westward, producing 3.0-4.0 PH values during the individual storms. Acid rain has improverished aquatic flora and fauna, lead to fish extermination, and caused low aquatic productivity in poorly buffered streams and lakes. Acid precipitation, which way also cause damage to forest growth, crop production, wildlife, and man-made materials such as buildings, metals, paints, and statuary, should be further investigated. Sensitive areas of North America should be identified so that field research programs can be focused geographically in those areas. (5 graphs)

Descriptors: *acid rain; *north america; *air pollution damage; *lakes; *water pollution damage; *aquatic ecosystems; *stack emissions; *forest ecosystems; tree damage; corp damage; poser plants-coal fired; fish kills; soil chemistry; food crops

Review Classification: 01

0152825 *81-005642

Speech by Ellis B. Cowling.

Presented At EPA Acid Rain Conf, VA, Apr 8-9, 80, P27 (54)

Technical feature mechanisms of atmospheric deposition associated with acid rain are examined. Anthropogenic sources of acid rain precursors, including industrial stack emissions and forestry activities, are identified. The consequences of acid precipitation have been documented; these include damage to vegetation and aquatic ecosystems and erosion of buildings and monuments. (1 diagram, G graphs, 2 maps, 30 photos)

Descriptors: *acid rain; *air pollution damage; *stack emissions; *water pollution damage; *legumes; *erosion; corrosion; aquatic organisms; sulfates; EPA conf paper

Review Classification: 01

0152091 *81-004933

Downwind: The Acid Rain Story,

Env Canada Report, 1981 (23)

Special report eastern portions of Canada and the U.S. are being affected by acid rain. Lake acidification, fish kills, crop damage, and weathered buildings are evidence of the damage resulting from such precipitation. Mechanisms of precursor transport and chemistry are surveyed. Emission controls must be placed on stationary and mobile sources. Coal, the main culprit responsible for sulfur dioxide emissions, can be washed to reduce the amounts of this precursor emitted to the atmosphere. (1 drawing, 1 graph, 4 maps, 23 photos)

Descriptors: *acid rain; *air pollution damage; *aqustic ecosystems; *sulfur dioxide; *nitrogen oxides; *atmospheric diffusion; *north america; *fish kills; soil chemistry; wildlife; buildings; erosion; health, env; transnational pollution

Review Classification: 01

0150655 *81-003545

Effect of Acid Rain on Structures,

Gauri K. LAL

Univ of Louisville,

Presented at ASCE Acid Rain Sym, Boston, Apr 2-6, 79, P70 (22)

Technical feature the effects of acid rain on marble used in the construction of architectural monuments and structures are discussed. Emphasized is damage suffered by the Georgia marble exposed on the exterior of the field museum of natural history in Chicago. Acid rain has caused chemical reactions to occur on marble surfaces, with resultant weathering, fracturing, and loss of sculptured details. (1 diagram, 2 graphs, 15 photos, 9 references 2 tables)

Descriptors: *acid rain; *weathering; *buildings; *air chemistry; *air pollution damage; urban atmosphere; conf paper

Review Classification: 01

0148464 *81-001462

Measuring the Social and Economic Impacts of Air Pollution Control Programs,

Savino Charles R.

Rice Center, Houston,

Presented at APCA Ozon/Oxidants: Interactions with the Total Env Conf, Houston, Oct 14-17, 79, P170 (14)

Technical Report Houston, Tex., and St. Louis, Mo., may be required to implement air pollution controls in addition to those already existing. A socioeconomic impact analysis methodology was developed to evaluate the regional social and economic consequences of such controls. Quantitative indicators used to measure impacts were regional economic growth, regional employment and population, average household income, personal mobility, and costs of controls to business. Analysis suggests that controls would be costly to households and business, would result in long-term reductions in metropolitan growth in Houston, would induce slight positive growth in St. Louis, and would significantly reduce hydrocarbon emissions. (2 diagrams, 2 references, 5 tables)

Descriptors: *econ impact-air poll cont; *air quality programs; *stack emission control; *emission control standards; *socioeconomic impact assess; *mathematic models-air; *mathematic models-economics; *economics, env-air; *Houston; St-Louis; employment; air poll cont investment; APCA conf paper

Review Classification: 01

0146954 81-000001
Air Pollution Effects on Social Policies,
Lave Lester B.
Carnegie-Mellon Univ,
ASHRAE Trans, 1979, V85, N2, P9 (5)
Survey report conflicts between the goals of environmental safety and energy conservation and the use of automobiles, industrial activity, and building heating and cooling are discussed. Problems inherent in the effort to achieve the objectives of various stringent environmental regulations that have been implemented during the past decade are examined. However, it is possible to balance the benefits and costs of environmental regulation. Scientific analysis of tradeoffs, of how to achieve stated goals, and of the real benefits of achieving these goals can help to eliminate some of the conflicts.
Descriptors: *ASHRAE conf paper; *air pollution effects; *socioeconomic impact assess; *law, env-fed; *emission control standards; *econ impact-air poll cont; *energy conservation; *cost benef analysis-air; automobile emission control; stack emission control; air quality stands, source; capital costs; automobile fuel economy
Review Classification: 01

0144251 80-004186
Ancient Polish City is Pollution Victim,
Darnton John
New York Times, Jun 8, 80, P5
News report damage to buildings and monuments caused by air pollution in Cracow, Poland, is reported. The central market of the town, which has been described as the finest surviving example of a medieval habitat, is threatened by heavy air pollution from surrounding industrial areas. The main cause of the air pollution is the widespread use of coal in Poland. Efforts to restore the older buildings in Cracow have begun.
Descriptors: *air pollution damage; *urban atmosphere; *Poland; *aesthetics, env-urban; *coal usage-region; urban renewal
Review Classification: 01

0143519 80-K00114
The Economic Impact of Air Pollution and Aircraft Noise on Residential Property Values; A Selected Bibliography,
1869-1977
Tomassoni Mark E.
Monticello. Ill. Council of Planning Librarians, 1978, 6 PP, $1.50 PA.
Technical feature
Descriptors: *airplane noise; *econ impact-air poll; *econ impact-noise poll; *real estate
Review Classification: 09

0142820 *80-002812
A Preference Approach to Measuring the Impact of Environmental Externalities,
Mark Jonathan J.
Univ of British Columbia,
Land Economics, Feb 80, V56, N1, P103 (14.)
Technical report the impact of air pollution on urban housing prices is examined through the development of a theoretical model that suggests that the relationship between externalities and property values may be interpreted in a preference context. Variables considered include sale prices, number of rooms in housing units, proximity of housing to central business districts, and air pollution data. Estimates of impacts are expressed as housing price differentials that are due to the externality. (22 references, 4 tables)
Descriptors: *air pollution effects; *urban atmosphere; *economics, env-land; *prices; *housing; *mathematic models-air; *mathematic models-economics; *mathematic models-land; econ impact-air poll; real estate
Review Classification: 01

0141365 80-001408
Distributional Analysis of Regional Benefits and Cost of Air Quality Control.
Loehman, E.T.; Berg S. V.; Arroyo A. A.; Hedinger R. A.; Schewartz J. M.; Shaw M. E.; Fahien R. W.
Univ of Florida,
J Env Economics & Management, Sep 79, V6, N3, P222 (22)
Technical report a cost-benefit analysis of air quality programs in urban areas of Florida is discussed. A mathematic model is developed to incorporate regional emission sources, ambient pollutant levels resulting from meteorological conditions, and the socioeconomic characteristics of impacted population groups. Results indicate that the requirements to use 0.5% sulfur fuel in urban power plants generates net household benefits to the majority of the population. (1 diagram, 2 graphs, 1 map, 41 references, 8 tables)
Descriptors: *urban atomosphere; *regional planning; *economics, env-air; *air poll cont investment; *power plant emissions; *mathematic models-air; *mathematic models-economics; *air pollution effects; health, env; Florida; econ impact-air poll cont; income comparisons
Review Classification: 01

0139962 *80-000056
Acid Rain: Research Summary,
EPA Report EPA-600/8-79-028. Oct 79 (23)
Special report described is EPA's program for investigating the existing U.S. acid rain problem and for building a data base for possible future regulatory actions. EPA research on the aquatic and terrestrial effects of acid rain, on monitoring techniques for acid precipitation. And on atmospheric processed causing acid precipitation are summarized. Acid rain studies at labs and universities throughout the U.S. are summarized. (1 diagram, 1 drawing, 2 graphs, 6 maps, 8 photos, 11 references)
Descriptors: *acid rain; *air pollution damage; *atmospheric pollutant deposition; *air chemistry; *area comparisons; *aquatic ecosystems; *forest ecosystems; *crop damage; eatershed management. Great lakes; PH hydrogen ION concentration
Review Classification: 01

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